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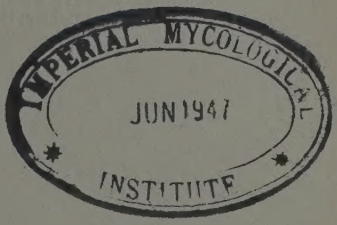

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TABLE DES MATIÈRES

Pages

MATHÉMATIQUES

M. Krein. On the Problem of Continuation of Helical Arcs in Hilbert Space . . . 139

ASTRONOMIE

V. B. Nikonov. Allowance for Atmospheric Extinction in Photoelectric Colorimetry of Stars 143

PHYSIQUE

M. W. Wolkenstein. On Intensity of Valence Vibrations in Infra-red Spectra . . . 147

PHYSIQUE APPLIQUÉE

M. M. Gurevich. Geometrical Solution of Colour Mixture Problems 149

ÉLECTRICITÉ

V. P. Nikitin, Member of the Academy, **V. K. Turkin** and **N. P. Kunitzki.** An Analytic Method for the Investigation of the Work of a D. C. Shunt Motor with Allowance for Saturation when the Speed of Revolution is Controlled by the Excitation Flux 153

CHIMIE PHYSIQUE

A. F. Belajev. On the Fundamental Principle of a Theoretical Calculation of the Work of Explosion 155

CHIMIE BIOLOGIQUE

M. M. Shemiakin and L. A. Shchukina. Experimental Study of the Mechanism Underlying the Biological Action of Quinones of the Vitamin K Type . . . 157

GÉOLOGIE

V. P. Baturin. Some Features of Chokrack Basin Palaeogeography in a New Aspect 159

MINÉRALOGIE

I. V. Popov. The Cryptostructure of Clays during their Deformation 162

PHYSIOLOGIE VÉGÉTALE

E. I. Ratner. On the Correlation between the Absorption by Plants of Water and Mineral Substances and on the Rôle of Internal Agents 165

MICROBIOLOGIE

K. S. Sukhov. On Certain Conditions of Formation of Intracellular Virus Inclusions 169

PARASITOLOGIE

I. M. Vinnitzky. A Comparative Study of the Defensive Reaction of the Organism of Various Animal Species to Parenterally Introduced Living Nematodes 173

Édition de l'Académie des Sciences de l'URSS

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1944. Volume XLV, № 4

MATHEMATICS

ON THE PROBLEM OF CONTINUATION OF HELICAL ARCS IN HILBERT SPACE

By M. KREIN

(Communicated by A. N. Kolmogoroff, Member of the Academy, 8.III.1944)

1. We shall call a continuous curve $\xi=\xi_t\,[t\in(a, b)]$ * in Hilbert space $\mathfrak{H}$ ($\xi\in\mathfrak{H}$) a helical arc, if for arbitrary r, $r+s$, $r+t$ belonging to the interval (a, b) the scalar product

$$B(s, t)=(\xi_{r+s}-\xi_r,\ \xi_{r+t}-\xi_r) \tag{1}$$

is completely determined by s and t and, consequently, does not depend on r**.

If, besides, $a=-\infty$, $b=\infty$, then the curve $\xi=\xi_t(-\infty<t<\infty)$ shall be called a helical curve.

It is easily seen that the necessary and sufficient condition for the curve $\xi=\xi_t(-\infty<t<\infty)$ to be a helical curve is that it must be representable in the form

$$\xi_t=K_t f\quad(-\infty<t<\infty) \tag{2}$$

where $K_t(-\infty<t<\infty)$ is a one-parametrical continuous group of motions of the space $\mathfrak{H}$, and f is a vector of $\mathfrak{H}$. The curves (2) were studied by A. Kolmogoroff [1] (where may be also found the exact definition of the group of motions K_t).

If the space $\mathfrak{H}$ is real (*i. e.* the product of a vector defined in it is only that by a real scalar, and the scalar product of any two of its vectors is always real), then the definition of a helical arc may be simplified, since the fact of the product (1) being independent of r is equivalent to the independence of r of the distance $\|\xi_{r+t}-\xi_r\|$ $[r, r+t\in(a, b)]$. This case of helical curve has been studied by J. von Neumann and J. Schoenberg [2].

In the sequel, if the contrary is not explicitely stated, $\mathfrak{H}$ will be supposed to be a complex Hilbert space.

A helical curve $\tilde{\xi}=\tilde{\xi}_t(-\infty<t<\infty)$ will be said to be a complete (helical) continuation of the arc $\xi=\xi_t\,[t\in(a, b)]$ if this arc is its segment, *i. e.* $\tilde{\xi}_t\equiv\xi_t$ for $t\in(a, b)$.

---

* The interval (a, b) is considered as closed, if it is finite, but if one of its ends lies in infinity, we do not count it to the interval. This remark refers also to the other intervals considered here.

** Thus, the function $B(s, t)$ is defined, in particular, for all s, $t\in(0, l)$, where $l=b-a$.

Denote by L_ξ the smallest closed linear manifold containing the arc ξ_t $[t\in(a, b)]$, *i. e.* the closure of the set of points η of the form

$$\eta=\sum_1^n \lambda_j \xi_{t_j} \quad (n=1, 2, \ldots), \tag{3}$$

where $t_j\in(a, b)$ $(j=1, 2, \ldots, n)$, and $\lambda_j (j=1, 2, \ldots, n)$ are arbitrary complex numbers, the sum of which is equal to one.

Theorem 1. *Every helical arc* $\xi_t [t\in(a, b),\ b-a<\infty]$ *has at least one complete helical continuation* $\tilde{\xi}_t (-\infty<t<\infty)$, *situated in* L_ξ*.

If the helical arc $\xi_t [t\in(a, b)]$ is not uniquely continuable, *i. e.* has different complete helical continuations, then those of them which are completely situated in L_ξ will be described as canonic continuations of the arc ξ_t.

2. We shall call a continuous arc $\xi_t [t\in(a, b)]$ a unitary arc, if there exists such a centre $p\in\mathfrak{H}$ that the scalar product $(\xi_t-p,\ \xi_s-p)$ is a function only of $t-s$. For $s=t$ from this condition, in particular, follows that the unitary arc is situated completely on a certain sphere $S(p, R)$ $(R>0)$, *i. e.*

$$\|\xi_t-p\|=R \qquad [t\in(a, b)]$$

It is easily seen that every unitary arc is a helical arc. Also that every unitary arc possesses a centre belonging to L_ξ. It may happen (cf. Theorem 3) that a unitary arc in L_ξ has more than one centre; in this case there must be an infinite set of centres. If $p\in L_\xi$ is a centre of the unitary arc $\xi_t [t\in(a, b)]$, then the point $q\in L_\xi$ $(q\neq p)$ will be a centre of the same arc if and only if

$$(q-p,\ \xi_t)=\alpha+i\beta t \quad [t\in(a, b)] \tag{4}$$

where α is a certain complex constant and β is a certain real constant different from zero. From (4) follows that if the unitary arc $\xi_t [t\in(a, b)]$ is a unitary curve (*i. e.*, $a=-\infty$, $b=\infty$), then it has one and only one centre in L_ξ. The distance of the unitary line $\xi_t (-\infty<t<\infty)$ from its centre $p\in L_\xi$ will be called the radius of this line.

The complete unitary continuation of a unitary arc will be defined similarly to the complete helical continuation of a helical arc.

Theorem 2. *Every unitary arc* $\xi_t [t\in(a, b),\ b-a\leq\infty]$ *with the centre* $p\in L_\xi$ *has one and only one complete unitary continuation* $\tilde{\xi}_t (-\infty<t<\infty)$ *with the same centre* p *and this continuation is always situated in* L_ξ.

Theorem 3. *If the helical arc* $\xi_t [t\in(a, b),\ b-a<\infty]$ *is not uniquely continuable, then it has an infinite set of canonic continuations. Among these continuations there is one and only one unbounded continuation* $\xi_t^0 (-\infty<t<\infty)$, *and it has the form*

$$\xi_t^0=ut+\eta_t \quad (-\infty<t<\infty) \tag{5}$$

where $\eta_t (-\infty<t<\infty)$ *is a certain unitary curve situated in* L_ξ, *and* u *is a certain vector from* L_ξ *orthogonal to* $\eta_t (-\infty<t<\infty)$.

All other canonic continuations $\xi_t^0 (-\infty<t<\infty)$ *of the arc* ξ_t *are unitary curves and their radii fill in a certain interval* (ρ, ∞). *Among these continuations there is one and only one continuation of minimal radius and two and only two continuations of any radius* $R>\rho$.

---

* If $a=-\infty, b<\infty$ or $-\infty<a,\ b=\infty$, then the existence of a complete helical continuation $\tilde{\xi}_t$ may be asserted only under the condition that the orthogonal complement to $\mathfrak{H}_\xi$ in $\mathfrak{H}$ is infinitely-dimensional. A. Kolmogoroff showed to the author that in these cases an arc may be found to have no continuations situated in L_ξ.

From Theorem 3 follows, in particular, that if the helical arc $\xi_t [t \in (a, b), b-a < \infty]$ is not uniquely continuable, then it is a unitary arc. It may be also shown that whatever be a linear closed separable manifold L containing L_ξ, and the centre $q \in L (q \overline{\in} L_\xi)$ of the arc ξ_t (not uniquely continuable), there is always an infinite set of different complete unitary continuations $\tilde{\xi}_t (-\infty < t < \infty)$ of the arc ξ_t having one and the same centre q and for which $L_{\tilde{\xi}} = L_\xi$.

From Theorems 2 and 3 also follows that a unitary arc is uniquely continuable to a unitary curve if and only if it has only one centre in L_ξ. This criterion breaks down if the underlying Hilbert space $\mathfrak{H}$ is supposed to be real (cf. the following remark).

Remark. If $\mathfrak{H}$ is a real Hilbert space, then the definition given for a unitary arc is equivalent to the definition of the unitary arc as a helical arc situated on a certain sphere, and the centre of the arc will be just the centre of any sphere containing this arc. Now the unitary arc ξ_t will have a unique centre in L_ξ which will be the orthogonal projection on to L_ξ of any other centre of this arc (L_ξ being, as before, the closure of the set of points $\eta \in \mathfrak{H}$ of the form (3), but with real λ_j). Theorems 1 and 2 remain valid. The formulation of Theorem 3 must be altered: a not uniquely continuable helical arc $\xi_t (-\infty < t < \infty)$ will now have only two canonic continuations: one ξ_t^e of the form (5) and the other, the unitary continuation the radius of which is less than the radii of all other complete unitary continuations of the arc.

3. In order to be able to formulate the following propositions we have to introduce some notations. By $\sigma(\lambda)$ $(-\infty < \lambda < \infty)$ we shall denote a bounded non-decreasing function normed in such a way that

$$\sigma(-\infty) = 0, \quad \sigma(\lambda) = \sigma(\lambda - 0) \quad (-\infty < \lambda < \infty)$$

and by L_σ the Hilbert space of all functions σ-measurable and σ-integrable together with their squares $f(\lambda)$ with the natural definition of the scalar product:

$$(g, f) = \int_{-\infty}^{\infty} g(\lambda) \overline{f(\lambda)} \, d\sigma(\lambda) \quad (g, f \in L_\sigma)$$

For arbitrary $t (-\infty < t < \infty)$ the function

$$\varphi_t(\lambda) = [\exp(it\lambda) - 1] \frac{\lambda + i}{\lambda} \quad (-\infty < \lambda < \infty)$$

evidently belongs to every L_σ.

Theorem 4. *To every helical arc $\xi_t [t \in (a, b)]$ there corresponds at least one non-decreasing bounded function $\sigma(\lambda)$ $(-\infty < \lambda < \infty)$ such that**

$$B(s, t) = \int_{-\infty}^{\infty} \varphi_s(\lambda) \overline{\varphi_t(\lambda)} \, d\sigma(\lambda) \tag{6}$$

If $b - a < \infty$, then the necessary and sufficient condition for the helical arc ξ_t to be uniquely continuable is that only one function $\sigma(\lambda)$ with the property stated should correspond to it.

For the helical curve the first part of Theorem 4 was established (in somewhat different terms) by A. Kolmogoroff (1).

The general case of the theorem might have been reduced to Kolmogoroff's case, if we should succeed in finding an existence proof of at least one complete continuation for every helical arc, not based (as it is the case in the present note) on Theorem 4.

---

* The definition of the function $B(s, t)$ is given in formula (1).

Denote by V_ξ the aggregate of all functions $\sigma(\lambda)$ corresponding in the sense stated in Theorem 4 to a helical arc $\xi_t\,[t\in(a,b)]$. In virtue of Theorem 4, if $\widetilde{\xi}_t$ is a complete continuation of the arc ξ_t, $V_{\widetilde{\xi}}$ consists of only one function $\sigma(\lambda)\in V_\xi$. This function $\sigma(\lambda)$ will be said to be generated by the complete continuation $\widetilde{\xi}_t$ of the arc ξ_t.

It may be easily shown that if two different continuations $\widetilde{\xi}_t$ and $\widetilde{\xi}'_t\,(-\infty<t<\infty)$ of one and the same arc generate the same function $\sigma(\lambda)$, then these continuations are equivalent, *i. e.* between $L_{\widetilde{\xi}}$ and $L_{\widetilde{\xi}'}$ an isometrical correspondence may be established in virtue of which $\widetilde{\xi}_t\leftrightarrow\widetilde{\xi}'_t\,(-\infty<t<\infty)$. Assuming that the orthogonal complement of L_ξ to $\mathfrak{H}$ is infinitely-dimensional, we may further assert that to every function $\sigma\in V_\xi$ there corresponds a certain class of equivalent complete continuations $\widetilde{\xi}_t$ of the arc $\xi_t\;[t\in(a,b)]$ generating it.

Starting from some function $\sigma\in V_\xi$, construct the function

$$g_\xi(t)=i\beta t+\int_{-\infty}^{\infty}\left[e^{it\lambda}-1-\frac{it\lambda}{1+\lambda^2}\right]\frac{1+\lambda^2}{\lambda^2}\,d\sigma(\lambda)\quad[t\in(-l,l),\ l=b-a] \tag{7}$$

where β is an arbitrarily chosen real constant.

In virtue of (6)

$$B_\xi(s,t)=g_\xi(s-t)-g_\xi(s)-g_\xi(-t) \tag{8}$$

The function $g(t)$ belongs to the class $\mathfrak{G}_l$ which we have investigated in an earlier paper ([3]). Using the denotations of this paper, we may in virtue of (8) assert that $V_\xi=V_g$. The theory of helical arcs hangs thus closely together with the theory of functions of the class $\mathfrak{G}_l$. Thus, for instance, every canonic continuation $\widetilde{\xi}_t$ of the arc ξ_t generates a canonic (in the sense of paper ([3])) function $\sigma(\lambda)\in V_g$, and conversely, every canonic function $\sigma(\lambda)\in V_g$ is generated by a certain canonic continuation $\widetilde{\xi}_t$ of the arc ξ_t. This fact has an interesting implication.

Let a certain function $\sigma(\lambda)$ and the function $g(t)\,[t\in(-l,l)]$ be connected by a relation of the type (7) [*i. e.*, $g(t)\in\mathfrak{G}_l$, $\sigma\in V_g$]. Then in order that the linear shell of the system of functions of λ $\varphi_t(\lambda)\;[t\in(0,l)]$ should be dense in L_σ, it is necessary and sufficient either that the function σ should be canonic, or that in V_g there should be no other functions except σ.

All results of the present and the preceding note were obtained on ground of our investigations on the generalized problem of moments ([4]). Their detailed proof will be found in our treatise «On certain special classes of Hermitian operators and the generalized problem of moments», which is being prepared for print.

V.V. Kuibyshev Industrial Institute.
Kuibyshev.

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ASTRONOMY

ALLOWANCE FOR ATMOSPHERIC EXTINCTION IN PHOTOELECTRIC COLORIMETRY OF STARS

By V. B. NIKONOV

(Communicated by G. A. Shajn, Member of the Academy, 6.IV.1944)

As is well known, the photoelectric colour-equivalents of stars are determined with very high accuracy. The application of antimonium-caesium photoelectric cells, which have a very wide colour system ([1],[2]), still more increased the internal accuracy of the observed colour-equivalents. This accuracy can be characterized by the following mean errors (μ) of one observation of the colour-equivalent (without allowance for extinction)

m	4.0 m	5.0 m	6.0 m	6.5 m	7.0 m	7.5 m
μ	$\pm$ 0.002 m	$\pm$ 0.002 m	$\pm$ 0.003 m	$\pm$ 0.004 m	$\pm$ 0.006 m	$\pm$ 0.009 m

These data are received by means of an antimonium-caesium photoelectric cell with a photometer ([3]) attached to the 13″ reflector. They are reduced to the international colour index scale, which is 1.7 times narrower than ours*.

In case of differential observations the reductions for atmospheric extinctions are insignificant, and do not practically affect the accuracy of observations even when using mean values of the extinction factor.

Things are different in the case of observations for fundamental electrocolorimetric catalogues. The corrections for colour extinction can here attain some tenths of stellar magnitude. Thus, allowance for the influence of the atmosphere, which ensures the conservation of the high accuracy of the initial observations, is a problem of high importance in that kind of work.

The widely adopted method of allowance for extinction based either on mean values ([4], [5]) or on values corrected by means of usual estimates of the transparency ([6]) does not guarantee the necessary accuracy of reduction. Moreover, such methods may involve systematic errors. These arise from seasonal change in the extinction and from a wrong mean value being adopted. The latter is apt to give a fictitious rate depending on declination. Systematic errors of that kind can lead to incorrect conclusions in such important questions, as the distribution of selective absorbing matter in galactic longitude or the natural dispersion in colours of stars. It may be shown that the application of the chain method in combination with mean values of extinction cannot ensure the absence of systematic errors of the above-mentioned type.

* In the following all data are reduced to the international scale.

The most reliable method of deriving the extinction is to use the observations of the standard stars (7). If the extra-atmospheric colour-equivalent C_0 of such a star is known, the extinction factor $\alpha\ (t)$ can be determined from the relation

$$C\,(z,\ t) = C_0 + \alpha\,(t)\,F\,(z) \tag{1}$$

where $C\ (z,\ t)$ is the colour-equivalent of the star observed at some instant t at a zenith distance z, and $F(z)$ is the air mass corresponding to this zenith distance.

Five or six observations of the standard star are sufficient for a reliable graphic interpolation of the extinction for any instant during the observation night.

We see that the problem of allowance for extinction is reduced to a precise determination of the extra-atmospheric colour-equivalents of standard stars. Unfortunately, the existing methods require a great number of auxiliary observations, while the generally adopted method of Bouger can sometimes lead to wrong results (8). Thus, it would be very important to use the very observations of the programme stars for the correction of the preliminary, arbitrarily adopted, value of the extra-atmospheric colour-equivalent of the standard star. Such a method is outlined below.

Let us suppose that the true value of the extra-atmospheric colour-equivalent C_0 is unknown and we make the reductions with some approximate value $C'_0 = C_0 - \Delta C_0$.

It is readily seen from formula (1) that the erroneous value of the extinction factor $\alpha'(t)$ will deviate from the true one $\alpha\ (t)$ by as much as

$$\Delta\alpha = -\Delta C_0 : F\,(z) \tag{2}$$

Let us see how the error ΔC_0 will affect the reduced colour-equivalents. Taking into consideration the dependence of the extinction factor on the colour-equivalent determined by the small value $\gamma = d\alpha/dC$, which can roughly be taken to be constant, we have obviously *

$$\begin{aligned} C'_{0*} &= C_*\,(z_*,\ t_*) - \alpha'\,(t_*)\,F\,(z_*) = \\ &= C_*\,(z_*,\ t_*) - \{\alpha'\,(t_*) + \gamma\,(C'_{0*} - C'_0)\}\,F\,(z_*) = \\ &= C_*\,(z_*,\ t_*) - \{\alpha\,(t_*) + \gamma\,(C'_{0*} - C'_0)\}\,F\,(z_*) + \eta\Delta C_0 \end{aligned} \tag{3}$$

By η for brevity sake is denoted the ratio of the air mass at which the given star was observed to the air mass corresponding to the zenith distance of the standard star at that instant:

$$\eta = F\,(z_*) : F\,(z) \tag{4}$$

Owing to the smallness of γ which even for the widest colour systems does not surpass some hundredths of a stellar magnitude, we can put

$$\gamma\,(C'_{0*} - C'_0) = \gamma\,(C_{0*} - C_0) \tag{5}$$

This is the more permissible, as usually C'_0 is taken close enough to C_0, and consequently, C'_{0*} will be close to C_{0*}.

Substituting (5) into formula (3) we find the fundamental relation

$$C'_{0*} = C_*\,(z_*,\ t_*) - \alpha_*\,(t_*)\,F\,(z_*) + \eta\Delta C_0 = C_{0*} + \eta\Delta C_0 \tag{6}$$

The error in the extra-atmospheric colour-equivalent of the programme star due to ΔC_0 is independent of the extinction value, but depends on η and, consequently, on the air mass at which the given star was observed.

It will be apparent that repeated observations of the same star, made at different η; will give different values for C'_{0*} according to ΔC_0. The difference of these values vill be equal to

$$\Delta C'_{0*} = \Delta\eta\Delta C_0 \tag{7}$$

It is on that equation that the method proposed here is based.

* We adopt for the programme stars the same notation as for the standard stars, but mark them with an asterisk in the subscript.

In principle a sole repeated observation of the programme star suffices for the determination of the correction sought for. But the presence of accidental observation errors and possible local unhomogeneities in the transparency of the atmosphere require that a number of equations (7) be solved by the least squares method. Ten or even five such equations suffice for deriving C_0 with a mean error $\sim \pm 0^m01$. It is necessary only that $\Delta\eta$ be as large as possible (the programme stars used for that purpose must not be too near to the standard one). Besides, it is desired to observe the stars in different azimuths. This will reduce the influence of the unhomogeneity of extinction. Moreover, it may be remarked that the repeated observations can be done at different nights, in other words, regular observations of the programme stars can be used for the determination of ΔC_0, provided that they have been carried out for different values of η.

It is customary, however, to make the observations near the meridian where the influence of extinction is the least. In this case $\Delta\eta$ will be very close to zero when the same standard star is used, and, consequently, $\Delta C_{0*}'$ will also be close to zero. Therefore even if the error ΔC_0 is great, the internal agreement of the catalogue will be excellent, in spite of a considerable systematic error. So the high accuracy of the catalogue will be fictitious.

Let us now consider some of the results obtained by the described method, while employing it regularly since the autumn of 1943 in the photoelectric colorimetry of B_s—B_9 stars.

Between September 1 and November 1 1943 we have used as standard star $\varkappa$ And. From 56 equations of condition relating to 11 nights within this period we have derived C_0 with a mean error of $\pm 0^m.002$. It must be noted that the values of C_0 received from separate nights disagree somewhat more than it would follow from the residuals in the solution of equation (7). Thus, if the mean error of the determination of C_0 for one night was found from the solution of the equations to be $\pm 0^m.008$ in the mean, the deviations of the received C_0 from their mean values yielded an error of $\pm 0^m.011$. Possibly, this gives some indication of small colour fluctuations of the standard star. It may also be noted that, as found earlier, the preliminary value of the colour-equivalent of the standard star C_0' does not practically affect the accuracy of the derived correction ΔC_0. For this value can even be taken the mean colour-equivalent referring to the spectral class of the given star.

To estimate the accuracy of the extra-atmospheric colour-equivalents of the programme stars as warranted by the application of the method considered, we observed systematically three stars: HD 1064, HD 19698 and HD 220222. These stars were observed at different η once or twice every night. The values of the mean error (μ_0) of one determination of extra-atmospheric colour-equivalent and the total number of the separate observations of these stars (n) are as follows:

*	m	μ_0	n
	m	m	
HD 1064	5.9	$\pm$ 0.006	21
HD 19693	5.7	$\pm$ 0.006	25
HD 220222	5.3	$\pm$ 0.004	31

For an additional estimate of the achieved accuracy we used also those repeated observations of the stars of our catalogue which were observed at different nights and did not enter into the formation of the equations of condition for the determination of ΔC_0. As only 44 stars had been observed in this way, we did not combine the received values of μ_0 into groups according to stellar magnitude. Joining them all, we find from all μ_0 a mean value of $\pm 0.^m005$, corresponding to the average magnitude $6^m.7$.

The obtained accuracy can be regarded as very satisfactory, seing that in the reduction for atmospheric extinction we unavoidably let without consideration a number of factors, namely, the fluctuations of extinction in the period between the observations of the standard star, the accidental errors in its observa-

tions, the effect of graphical smoothing of the changes in $\alpha(t)$ and possible local unhomogeneities of the transparency. We have neglected also the small effect of variations in γ. Besides, slight fluctuations of colour in the standard, as well as in the programme stars, may possibly have here some influence, too.

It seems of interest to refer here for the sake of comparison to the accuracy of some catalogues of photoelectric colours received with potassium photoelectric cells, using either mean extinction factors, or those corrected by eye estimates.

		m
Stebbins and Huffer [6]	$\mu_0 =$	± 0.031
Becker [5]		± 0.022
Güssow [8]		± 0.042

It is apparent that because of the advantages of a wide colour system offered by the antimonium-caesium photoelectric cell, the method proposed essentially increases the accuracy of the determination of colour-equivalents of stars. Its other advantage is that no auxiliary observations, except the current observations of the standard star, are required.

It must be noted in conclusion that allowance for atmospheric extinction, according to the method applied here to a colometric catalogue, can be also used for the derivation of a fundamental system of photoelectric stellar magnitudes. A necessary condition to be fulfilled is to secure the stability of the photometric sensitivity of the photometer [9], or to have reliable means for controlling it. This may be effected with the aid of a photometric standard made of a radioactive dye [3].

Central Astronomical Observatory,
Academy of Sciences of the USSR.
Abastumani Astrophysical Observatory,
Academy of Sciences of the Georgian SSR.

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PHYSICS

ON INTENSITY OF VALENCE VIBRATIONS IN INFRA-RED SPECTRA

By M. W. WOLKENSTEIN

(Communicated by S. I. Wavilow, Member of the Academy, 31.III.1944)

In an earlier communication (1) the author has dealt with a Raman line corresponding to a completely symmetrical valence vibration of a group of N similar bonds forming equal angles γ with each other, and discussed the dependence of the intensity and polarization of this line upon N and γ. Let us now solve the same problem for the infra-red vibrational line. Making use again of the zero approximation theory (2,3), we shall obtain the following formula for the intensity of a completely symmetrical valence vibration:

$$I_N^s \sim \sum_{i=x,y,z} \left(\frac{\partial p_i}{\partial Q}\right)_\gamma^2 = \sum_i \left(\sum_{n=1}^{N} \frac{\partial \mu_n}{\partial q_n} \cos(ni) \frac{\partial q_n}{\partial Q}\right)^2 =$$

$$= \left(\frac{\partial q}{\partial Q}\right)^2 \mu'^2 \sum_i \left(\sum_n \cos(ni)\right)^2 = \left(\frac{\partial q}{\partial Q}\right)^2 \mu'^2 N\{1+(N-1)\cos\gamma\} \qquad (1)$$

Here p_i are the components of the electric moment of the molecule; μ_n is the moment of an individual bond; μ' is its derivative with respect to the variation of the bond length—the effective charge of the bond. By virtue of equation (2) of the previous paper (1)

$$I_N^s \cong I_1\{1+(N-1)\cos\gamma\} \qquad (2)$$

If γ is a tetrahedral angle (case CH, CH_2, CH_3, CH_4)

$$I_2^s \cong \frac{2}{3} I_1, \quad I_3^s \cong \frac{1}{3} I_1, \quad I_4^s = 0 \qquad (3)$$

However, it is antisymmetrical rather than symmetrical vibrations that are the most intensive and typical in infra-red spectra. Considering the problem in the general form, we shall not arrive here to a simple formula, for we have to deal with degenerated vibrations.

The formulae deduced in the above-cited papers (2,3) give:

$$\left.\begin{array}{l} \text{Case } XY \quad I_1 \sim C_1^2 \mu'^2 \\ \text{Case } XY_2 \; I_2^{as} \sim C_2^2 2\mu'^2 \;(1-\cos\gamma) \\ \text{Case } XY_3 \; I_3^{as} \sim C_3^2 3\mu'^2 \;(1-\cos\gamma) \\ \text{Case } XY_4 \; I_4^{as} \sim C_4^2 12\mu'^2 (1-\cos\gamma) \end{array}\right\} \qquad (4)$$

For invariable frequencies and constant bonds (characteristic vibrations)

$$C_2^2 = C_3^2 = \frac{1}{2} C_1^2; \quad C_4^2 = \frac{1}{4} C_1^2 \tag{5}$$

and for tetrahedral angles we obtain

$$I_2^{as} \cong \frac{4}{3} I_1; \quad I_3^{as} \cong 2I_1; \quad I_4^{as} \cong 4I_1 \tag{6}$$

The most characteristic bands in the case of infra-red spectra increase in intensity with the number of like bonds. The author's computations corroborate the experimental data of B. Timm and R. Mecke (4) who have compared the intensities of the third overtones of C—H vibrations in a series of halogen substituted derivatives of hydrocarbons.

In infra-red spectra the intensities of valence vibrations are determined by the values of effective charges μ'. On the other hand, if the values of the dipole moments μ are known, the μ' can be determined by comparing the intensities of valence vibrations and deformation vibrations. A more reliable way of determining the μ' is from the course of dispersion in the infra-red region. In the case of gas

$$n^2 - 1 = \sum_i \frac{K_i}{\omega^2 - \omega_i^2} \tag{7}$$

The forces of the oscillators K_i are proportional to $1/C^2 (\partial p/\partial Q)^2$. Our theory permits the μ' to be found when the K_i, μ and the forms of the corresponding vibrations are known. Thus, making use of Rollefson and Havens' (5) data on the dispersion of methane in the infra-red region, we obtain for the C—H bond

$$\mu' = \pm 0.3 \cdot 10^{-10} \text{CGSE} = \pm 0.06\, e \tag{8}$$

This value comes near to the ratio $\mu : r_0 = 0.37 \cdot 10^{-10}$.

The sign of μ' remains yet undeterminate. But it may be remarked in this connexion that even concerning the direction of the dipole of the C—H bond, there is no concurrence of opinion up to the present (6).

Laboratory of Spectrum Analysis.
State Optical Institute.

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TECHNICAL PHYSICS

GEOMETRICAL SOLUTION OF COLOUR MIXTURE PROBLEMS

By M. M. GUREVICH

(Communicated by S. I. Wawilow, Member of the Academy, 4.IV.1944)

The different ways of solving colorimetric problems have been widely discussed in literature ([1–3]). At present the following principal methods have asserted themselves in the domain of colorimetric computations, though all of them have not been formulated precisely.

1. Take for primary colours three arbitrary colours $\vec{R}$, $\vec{G}$ and $\vec{V}$ represented by three non-coplanar vectors laid off in three arbitrary directions from point O (Fig. 1). Through the end-points of these vectors draw the plane P. Every colour represented by an arbitrary point C of plane P is agreed upon to be the unit colour of the direction OC. Then the position of the point C in the plane P will determine the chromaticity of the colour represented by the vector $\vec{OQ}$ whose direction coincides with OC.

We will use the term «colour modulus» to describe the ratio of the length of an arbitrary colour vector $\vec{OQ}$ to the unit vector $\vec{OC}$ having the same direction. Making use of this term*, we can thus set forth the principal statements employed in colorimetric calculation:

a) The modulus of a mixture of two or more colours is equal to the sum of the components' moduli.

b) In order to find in the plane P the position of the point C which represents the chromaticity resulting from a mixture of two or more colours, we proceed as if we had to find the centre of gravity of two or more weights, the weight of colour corresponding to its modulus, and the position of the weights coinciding with the position of the chromaticities of the mixed components.

Any colour Q can be represented as a mixture of three primary colours R, G, V taken in certain proportions r', g', v' which are this colour's coordinates in the system R,G,V, so that

$$Q = r'R + g'G + v'V \qquad (1)$$

Applying hereto the statement (a), we find the modulus

$$m = r' + g' + v' \qquad (2)$$

To put it into words:

c) The modulus of a colour is equal to the sum of colour's coordinates.

* So far as I am aware, the notion of colour modulus has first been suggested by S. O. Maizel.

It follows from this that the moduli of all unit colours represented by the points C of the plane P are equal to unity, since this plane is described by the equation $r+g+v=1$*.

On the other hand, the colour modulus representing the length ratio between the vectors $\overrightarrow{OQ}$ and $\overrightarrow{OC}$ (Fig. 1) we can also express as the ratio of any coordinate of the colour Q to the respective coordinate of the unit colour C; so that

$$m=r'+g'+v'=\frac{r'}{r}=\frac{g'}{g}=\frac{v'}{v}$$

2. In the case of a mixture of two colours Q_1 and Q_2 having the chromaticities C_1 and C_2 and moduli m_1 and m_2, respectively, it is known that the point C determining the chromaticity of the mixture is located on the straight line C_1C_2 and divides it in the ratio

$$CC_1 : CC_2 = m_2 : m_1 \qquad (3)$$

For a mixture of three colours Q_1, Q_2 and Q_3 with chromaticities C_1, C_2 and C_3 (Fig. 2) the position of the point C characterizing the chromaticity

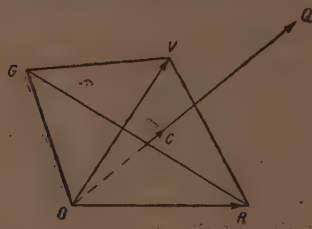

Fig. 1

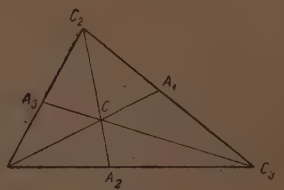

Fig. 2

of the mixture is determined by the following relations. Denoting as before by m_1, m_2, m_3 and m the respective moduli of the components Q_1, Q_2, Q_3 and of their mixture Q, we have

$$m=m_1+m_2+m_3 \qquad (4)$$

and

$$\frac{CA_1}{C_1A_1}=\frac{m_1}{m}; \quad \frac{CA_2}{C_2A_2}=\frac{m_2}{m}; \quad \frac{CA_3}{C_3A_3}=\frac{m_3}{m} \qquad (5)$$

It is obvious that

$$\frac{CA_1}{C_1A_1}+\frac{CA_2}{C_2A_2}+\frac{CA_3}{C_3A_3}=1$$

These relations may be found to be useful in solving colorimetric problems by the graphical method.

3. The relations between colour moduli that make possible the use of a geometric method of calculation will not at once give the value of colour brightness, which is in many cases the ultimate object of the calculation. Among the cited authors N. Boldyrev (°) has alone suggested a simple method for determining the brightness ratio graphically. But there are other methods to attain this end which are not inferior to Boldyrev's in respect to simplicity. Naturally enough, the international XYZ system is particularly suitable for this purpose.

* The coordinates of unit colours are usually denoted by respective letters without touches.

Let us pply to it the general statements derived above. It is known that in the XYZ system the brightness B of a colour Q is measured in terms of its coordinate y', so that $y' = B$.

The colour modulus can therefore be represented thus:

$$m = x' + y' + z' = \frac{y'}{y} = \frac{B}{y} \tag{6}$$

Turning to Fig. 3, we will once more consider the case of a two-colour mixture. According to (3)

$$CC_1 : CC_2 = m_2 : m_1 = \frac{B_2}{y_2} : \frac{B_1}{y_1}$$

where B_1 and B_2 are brightnesses of the colours Q_1 and Q_2, respectively, and y_1 and y_2 are the ordinates of their chromaticities C_1 and C_2.

Draw the straight line C_1H_2 and denote by N its intersection with CH. It is easy to see that the sought-for relation will be $\frac{B_2}{B_1} = \frac{CN}{NH}$.

In fact

$$\frac{CN}{y_2} = \frac{CC_1}{C_1C_2} \quad \text{and} \quad \frac{NH}{y_1} = \frac{CC_2}{C_1C_2}$$

Hence

$$\frac{CN}{NH} = \frac{CC_1}{y_1} : \frac{CC_2}{y_2} = \frac{B_2}{B_1} \tag{7}$$

If C_1 is a white colour, and C_2 a monochromatic colour, then the colorimetric purity is

$$p = \frac{CN}{CH}$$

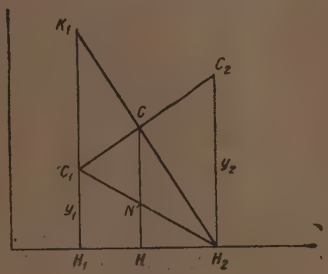

Fig. 3

If the problem is put otherwise and we are given no hues to derive the brightness ratio, but have instead to determine the position of point C when the brightness ratio (between B_1 and B_2) is known; then we proceed as follows.

We produce the line H_1C_1, lay off on it an intercept $C_1K_1 = y_1\frac{B_2}{B_1}$ and draw the straight line K_1H_2. It will cross the line C_1C_2 at a point C which, as is easily seen, determines the chromaticity of the mixture.

When three colours Q_1, Q_2 and Q_3 are mixed and their chromaticities are C_1, C_2 and C_3, respectively, it may be interesting to find what share the brightness of someone of them (no matter which) has in the formation of the mixture whose chromaticity is represented by the point C (Fig. 4).

Draw the line C_1C and produce it up to the point A_1. Connecting the points A_1 and H_1 by a straight line and denoting by N the point of its intersection with CH, we shall find that $\frac{CN}{y_1} = \frac{CA_1}{C_1A_1}$. On the other hand, by virtue of (5)

$$\frac{CA_1}{C_1A_1} = \frac{m_1}{m} = \frac{B_1}{y_1}\frac{y}{B}$$

From these two expressions we obtain

$$\frac{B_1}{B} = \frac{CN}{y} = \frac{CN}{CH} \tag{8}$$

Finally, being given the brightness ratios $B_1 : B_2 : B_3$ of three colours whose chromaticities C_1, C_2 and C_3 (Fig. 5) are known, we can determine the chromaticity of the mixture by proceeding in the way indicated by our

previous reasoning. On the produced lines H_1C_1 and H_3C_3 we lay off the intercepts C_1K_1 and C_3K_3 such that

$$C_1K_1 = y_1 \frac{B_2}{B_1} \quad \text{and} \quad C_3K_3 = y_3 \frac{B_2}{B_3}$$

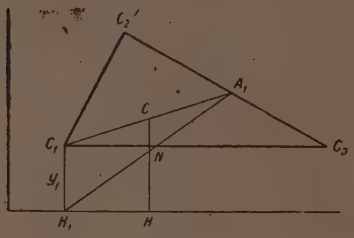

Fig. 4

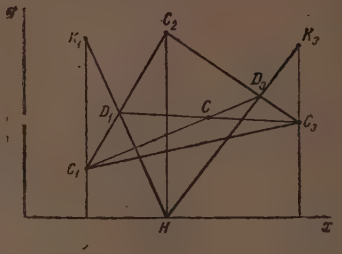

Fig. 5

Straight lines drawn from K_1 and K_3 to H_2 will intersect with C_1C_2 and C_3C_2 at points D_1 and D_3. These points we connect with C_3 and C_1, respectively, by means of straight lines whose mutual intersection will give the point C determining the chromaticity of the mixture.

Photometric Laboratory,
State Optical Institute.

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ELECTRICAL ENGINEERING

AN ANALYTIC METHOD FOR THE INVESTIGATION OF THE WORK OF A D. C. SHUNT MOTOR WITH ALLOWANCE FOR SATURATION WHEN THE SPEED OF REVOLUTION IS CONTROLLED BY THE EXCITATION FLUX

By V. P. NIKITIN, Member of the Academy, V. K. TURKIN and N. P. KUNITZKI

While discussing this subject before (1) we supposed the motor to work in the unsaturated portion of the no-load run characteristic. In the present paper the saturation is taken into account.

Only rarely is it possible to find a more or less accurate analytic expression for the no-load characteristic in the form of a not to cumbersome formula. Therefore the customary way in this case is to use grapho-analytic methods for an approximate integration of differential equations. Yet grapho-analytic methods alone do not supply an answer to every practically important question.

In this paper a curvilinear no-load characteristic is approximated to a broken line composed of several rectilinear segments. With this substitution the magnetic flux Φ for every straight portion is connected with the excitation current i_b by the relation

$$\Phi = m_\lambda i_b + a_\lambda$$

where m_λ is the tangent of the inclination angle of an λ-th segment, and a_λ is the intercept cut off by the respective straight line on the axis of ordinates.

To simplify the problem we disregard the influence of the armature's inductance and reactance, and the damping effect of eddy currents, so as to proceed from the following system of equations

$$U = Ri + c\Phi n, \quad M = M_s + \frac{GD^2}{375}\frac{dn}{dt}, \quad M_s = A + Bn,$$
$$M = k\Phi i, \quad \Phi = mi_b + a, \quad U = r_b i_b + L_b \frac{di_b}{dt}. \tag{1}$$

Here U is voltage at the terminals of the motor; i, armature's current; R, resistance of the armature; Φ, magnetic flux of the motor; n, its number of revolutions per minute; M, its moment; GD^2, the torque of the drive; M_s, moment of static resistance of the mechanism; A, intercept cut off on the ordinate axis by the characteristic of the mechanism $M_s = f(n)$, or, in other words, the moment of resistance for $n = 0$; $B = dM_s/dn$; i_b, the excitation current of the motor; r_b and L_b, resistance and inductance of the motor's excitation circuit; m, tangent of the angle of slope (to the abscissa) of the respective segment of the broken line (approximated) characteristic $\Phi = f(i_b)$; a, intercept cut off by the respective straight line on the ordinate axis; c and k are coefficients whose values vary according to the construction of the particular system.

From (1) we have

$$i_b = -\frac{U}{r_b} + Ce^{-\frac{r_b}{L_b}t},$$

where C is the arbitrary constant of integration. The variable i can be expressed through n according to the formula

$$i = \frac{U - c\Phi n}{R} = \frac{U - c\left[m\left(\frac{U}{r_b} + Ce^{-\frac{r_b}{L_b}t}\right) + a\right]n}{R},$$

and for n we get the differential equation

$$\frac{GD^2}{375}\frac{dn}{dt} + A + Bn = k\left[m\left(\frac{U}{r_b} + Ce^{-\frac{r_b}{L_b}t}\right) + a\right]\frac{U - c\left[m\left(\frac{U}{r_b} + Ce^{-\frac{r_b}{L_b}t}\right) + a\right]n}{R} \quad (2)$$

By means of the substitution $e^{-\frac{r_b}{L_b}t} = z$ equation (2) is reduced to the form

$$\frac{dn}{dz} - \frac{\alpha z^2 + \beta z + \gamma}{z}n = \frac{\delta z + \varepsilon}{z} \quad (3)$$

where

$$\alpha = \frac{375C^2L_bckm^2}{GD^2Rr_b}, \quad \beta = \frac{750CL_bUckm^2}{GD^2Rr_b^2}, \quad \gamma = \frac{375L_b}{GD^2r_b}\left[B + \frac{ck}{R}\left(\frac{U^2m^2}{r_b^2} + a^2\right)\right],$$

$$\delta = -\frac{375CL_bUkm}{GD^2Rr_b}, \quad \varepsilon = \frac{375L_b}{GD^2r_b}\left[A - \frac{Uk}{R}\left(\frac{Um}{r_b} + a\right)\right]$$

As has been shown in paper (1), the solution of (3) has the form:

$$n = \left(\sqrt{\frac{\alpha}{2}}\right)^{\gamma-1}\exp\left[\frac{\alpha}{2}\exp\left(-\frac{2r_b}{L_b}t\right) + \beta\exp\left(-\frac{r_b}{L_b}t\right) - \right.$$

$$\left. - \gamma\frac{r_b}{L_b}t\right] \times \left\{\delta\Psi\left[\sqrt{\frac{\alpha}{2}}\exp\left(-\frac{r_b}{L_b}t\right), \quad \beta\sqrt{\frac{2}{\alpha}}, \quad \gamma\right] + \right.$$

$$\left. + \varepsilon\sqrt{\frac{\alpha}{2}}\Psi\left[\frac{\alpha}{2}\exp\left(-\frac{r_b}{L_b}t\right), \quad \beta\sqrt{\frac{2}{\alpha}}, \quad \gamma + 1\right] + C'\right\}$$

where C' is an arbitrary constant of integration. The function

$$\Psi(v, \lambda, \mu) = \int_1^v e^{-(h^2 + \lambda h)}h^{-\mu}\,dh$$

was introduced in (1).

Here, as in (1), the condition for the stability of the process is $\gamma > 0$.

As the quantities GD^2, r_b, L_b are positive, this condition can be rewritten as follows

$$B + \frac{ck}{R}\left(\frac{U^2m^2}{r_b^2} + a^2\right) > 0 \quad (4)$$

For settled values of the variables (in the case of a stable process) we have the following relations:

$$i_{b\text{settled}} = \frac{U}{r_b} \quad (5)$$

$$n_{\text{settled}} = \frac{Ukr_b(Um + ar_b) - ARr_b^2}{ck(U^2m^2 + a^2r_b^2) + BRr_b^2} \quad (6)$$

$$i_{\text{settled}} = \frac{BRUr_b^2 + ARcr_b(Um + ar_b) - 2Uackmr_b}{R[ck(U^2m^2 + a^2r_b^2) + BRr_b^2]}. \quad (7)$$

The values of m and a in (4), (6) and (7) are to be selected to correspond to that portion of the broken characteristic $\Phi = f(i_b)$ which includes the point having $i_{b\text{settled}}$ for abscissa.

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PHYSICAL CHEMISTRY

ON THE FUNDAMENTAL PRINCIPLE OF A THEORETICAL CALCULATION OF THE WORK OF EXPLOSION

By A. F. BELAJEV

(Communtcated by N. N. Semenov, Member of the Academy, 11.III.1944)

Even in the very old text-books on the theory of explosives one may encounter the correct; scientifically grounded statement that the work of explosion should be considered as the work of the adiabatic expansion of the gases it liberates. Nevertheless; the further development of this idea as well as a comparison of the conclusions following from it with experimental data were practically neglected. The recently published investigations of Schmidt (1), and Taylor and Morris (2); even though they may be regarded as a step forward in the development of the above problems; are insufficient and considerably narrow it down.

Thus; Schmidt actually considers the total possible work of explosion upon expansion to atmospheric pressure. Moreover; he considers not real substances; but some «ideal»; abstract substances.

Even in recent text-books on explosives one comes upon incorrect statements characteristic of which is an attempt to appraise the possible work of explosion by some constant quantity. Among such constant quantities figure the energy of explosion; the characteristic Berthelot product; the «force» of explosion or the «specific energy»; the «spectific pressure»; *etc.*

The author of this paper in collaboration with A. E. Belajeva has made an attempt to calculate the work of explosion for definite substances as a function of the degree of expansion of the gases liberated. In that investigation we assumed that separate forms of mechanical work of explosion are proportional not to the total work capacity; but to the work at a certain definite expansion.

Let us consider an explosive charge planted not too deep under ground. Upon exploding the gases liberated will begin to expand; performing work—squeezing; breaking up and throwing out the ground in the neighbourhood of the explosion source. At a certain instant; the sphere of destruction will approach the surface of the ground; and the gases will break through to the outside. As they do so; they may still be able to perform work; but this work will be expressed in the formation of an air blast; this part of the total work of explosion will not be connected in any way with the work of breaking up and throwing out the ground. Therefore the latter must be assumed to be proportional not to the total work of explosion; but to the part that is expended in expanding the gases from their initial volume to the instant they burst out into the atmosphere. In case the liberated gases are not able to break through to the outside, all of the work will be performed inside the ground, but its magnitude will be unquestionably less than the maximum work in expansion up to atmospheric pressure.

The calculations were carried out for explosives of diverse characteristics: pentaerythrotetranitrate, trotile; amatole 80/20, ammonite 88/12, ammonal 80/20; dynamone-T, lead azide; mercury fulminate; *etc.* As was already pointed out above, the work was calculated as a function of the degree of expansion V_2/V_1; where V_1 is the initial volume and V_2 is the volume at the instant for which the work is being calculated.

As follows from the general thermodynamic relations of the work; $A = \bar{c}_v (T_1 - T_2)$; where $\bar{c}_v$ is the mean heat capacity within the interval $T_1 - T_2$; T_1

is the initial temperature; and T_2 is the final temperature (corresponding to the volume V_2); $T_2 = T_1(V_1/V_2)^{k-1}$, where $k = \bar{c}_p/\bar{c}_v$.

On calculating the value of A for a number of volumes V_2, we obtain a complete picture of the increase in work with an increase in the degree of expansion. The following conclusions may be drawn from the curves $A = f(V_2/V_1)$: if two different substances, B and C, are considered, the ratio of the values of the work A_B/A_C will depend upon the degree of expansion, *i. e.* it will be a variable quantity. For all practical purposes, the ratio A_B/A_C for substances, having close values of T_1, $\bar{c}_v$, $\bar{c}_p/\bar{c}_v$, will change but little, but in some cases the change will be quite noticeable (*e. g.* the ratio A_B/A_C markedly changes depending upon the degree of expansion for the case of ammonal—amatol). This points to the principal impossibility of characterizing the relative work capacity by some definite number.

All the above-said has a direct bearing on the problem of the general effect of an explosion. Depending upon the location of the charges in the ground, the gases will break through into the atmosphere at a different degree of expansion. It follows from this that the «coefficient of ability to perform work for explosives» should be a variable quantity and depend upon the exponent of throwing out. Only for substances akin in their properties may it be regarded as constant.

An analysis of results obtained solves automatically the problem of the influence of the specific volume of the gases liberated by the explosion. The volume of the gases affects the magnitude of the work through the adiabatic exponent k. The work of explosion depends quite markedly upon the specific volume of the gases, this dependence being the greater; the less the degree of expansion.

The characteristic distinction between the local and general effect is the slight dependence of the latter upon the density of the charge (at constant mass) and upon the magnitude of the co-volume, as compared with the former. Upon analysing the curves $A = f(V_2/V_1)$, it may be noted that the work of explosion at average and large expansions depends slightly upon the density and the magnitude of the co-volume, as compared with the work of explosion at very small expansions. If one takes into account the parallelism in certain other respects and the fact that the local effect makes itself felt on objects in the direct vicinity of the explosion source, one may draw the conclusion that the work of the locan action is the work of adiabatic expansion of the gases liberated by the explosiol at small expansions, while the work of the general action relates to medium and large degrees of expansion. This conclusion requires further development and correlation with the existing notions on the local effect.

The examples cited are sufficient to show that the development of the concept of the work of explosion as the work of adiabatic expansion leads to interesting and important conclusions.

In addition, the possibility opens up for a new approach to the problem of an appraisal of the air blast as well as several other explosion effects.

In conclusion we shall dwell upon some problems connected with the testing of explosives. In determining the relative capacity to perform work of the general action by explosives; it is quite important to compare the work at identical expansions. The test most widely used in our industry—the Trauzl bomb—cannot be considered successful in this respect; since the relative work capacity is appraised on the basis of the magnitude of expansion; *i. e.* a different degree of expansion lies at the basis of the method.

The situation is entirely different in tests with the ballistic pendulum described by Taylor and Morris (2). In this test (which, by the way, makes it principally possible to measure the explosion work in absolute units) the work capacity of explosives may be determined at identical degrees of expansion.

Institute of Chemical Physics.
Academy of Sciences of the USSR.

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BIOCHEMISTRY

EXPERIMENTAL STUDY OF THE MECHANISM UNDERLYING THE BIOLOGICAL ACTION OF QUINONES OF THE VITAMIN K TYPE

By M. M. SHEMIAKIN and L. A. SHCHUKINA

(Communicated by V. M. Rodionov, Member of the Academy, 10.IV.1944)

On the basis of chemical and biochemical investigations of compounds endowed with antihaemorrhagic activity, the writers have put forward the hypothesis (1; 3) that the antihaemorrhagic effect of quinones of the vitamin K group is due to their oxidative biochemical degradation to phthalic acid, and is to a considerable degree a function of their capacity to be transformed into the latter. Phthalic acid should be regarded as the true carrier of biological properties of this kind of quinones.

This statement ensued from the following facts established experimentally.

1. Quinones of the type of vitamin K are excessively easily converted into phthalic acid—simply by heating with water (2).

2. The same structural properties that account for their antihaemorrhagic effect, account also for the easy conversion of these quinones into phthalic acid (3).

3. The latter quality is connected with the tautomeric conversion of thermolecules into a peculiar alicyclic system; remarkable for its easy oxidation to phthalic acid(1—3).

4. On the other hand; it has been found that phthalic acid itself shows a feeble antihaemorrhagic effect and that some of derivatives even possess considerable antihaemorrhagic activity. The reason for the lower activity of phthalic acid as compared to diethyl phthalate or to quinones of the vitamin K type, can be explained probably by the rapid elimination of the former from the organism (3).

5. Quinones of the vitamin K type undergo a rapid change in the blood (5), although their antihaemorrhagic activity does not appear until a consiberable time later. This shows as well that this kind of quinones does not probably exist in the organism at the instant when the antihaemorrhagic effect is dbiplayed, and that the latter is brought about not by the quinones; but by their slransfor mation products.

If we were to prove the fact that conversion of quinones in question to phthalic acid takes place in the organism; this evidence would speak strongly in favour of our opinion concerning the mechanism of their biological action. Accordingly, we undertook the study of the metabolism both of phthalic acid and of 2-methyl-1,4-naphthoquinone (vitamin K_3) within the organism of dog and man.

Repeated hypodermic injections to dogs (weight 12—13 kg) of considerable doses of a rather concentrated aqueous solution of the bisulphite derivative of 2-methyl-1, 4-napqthoquinone (in all about 0.8 g) led to the isolation from the urine of phthalic acid, identified as phthalic anhydride, and at the same time

proved the absence in the urine of 2-methyl-1, 4-naphthoquinone and of its bisulphite derivative* as well as of 2-methyl-3-hydroxy-1;4-naphthoquinone (phthiocol)**.- After a hypodermic injection to man of 50 mg of the bisulphite derivative of 2-methyl-1; 4-naphthoquinone, dissolved in water, in the urine the presence of phthalic acid was also stated. However, phthalic acid itself, or its di-sodium salt; introduced in an aqueous solution hypodermically, practically are eliminated from the organism of dog and man without any changes, as it has been shown by Pohl (6) on dogs and by the authors on man. In the urine of a control man and dog; kept on a diet not containing vitamin K, phthalic acid is absent. It follows from this that phthalic acid is the final product of the metabolism of 2-methyl-1; 4-naphthoquinone.

Thus; the hypothesis advanced by the authors concerning the mechanism of the biological activity of quinones of the vitamin K group is confirmed not only by the antihaemorrhagic activity of phthalic acid, but also by the capacity of this kind of quinones to be converted into phthalic acid both *in vitro* and *in vivo*.

In conclusion we would like to dwell upon the work of Link et al. (7) concerning the mechanism of the haemorrhagic activity of 3,3′-methylene-4; 4′-dihydroxy-dicoumarin; which is an antagonist of vitamin K. These authors have demonstrated that salicylic acid shows the same kind of biological action as 3,3′-methylene-4, 4′-dihydroxy-dicoumarin and; being probably a product of its metabolism in the organism, can be looked upon as the carrier of its haemorrhagic functions.

These data become of special interest if they are compared with our investigations from which it follows that phthalic acid is not only the final product of metabolism within the organism of quinones of the vitamin K type; but is probably the carrier of the antihaemorrhagic functions of the latter as well.

Laboratory for the Chemistry of Vitamins.
All-Union Institute of Experimental Medicine.

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* M. M. Shemiakin, in collaboration with D. A. Bochvar, has proved at present experimentally that the crystalline bisulphite derivative obtained by the reaction of 2-methyl-1,4-naphthoquinone with sodium or potassium bisulphite is 3-monohydro-2-methyl-naphthalene-1-ol-4-one-3-sulphonate (I), and not the addition product of a molecule of sodium bisulphite to one of the carbonyl groups of 2-methyl-1, 4-naphthoquinone, as it has been asserted by Palladin (8) and Ufimtzev (9). In aqueous solutions this compound (I) is in equilibrium with 2-methyl-1, 4-naphthoquinone -3-sulphonate, on the one hand, and with a peculiar bisulphite complex, being a resonance of several structures, in which H^+ and $SO_3^{''}$ ions of the bisulphite molecule are bound with different carbonyl groups of 2-methyl-1, 4-naphthoquinone, on the other hand. This complex, in its turn, is in equilibrium with the corresponding oxonium salt and further, with free 2-methyl-1, 4-naphthoquinone. The existence in an aqueous solution of this kind of equilibrium between 3-monohydro-2-methyl-naphthalene-1-ol-4-one-3-sulphonate and free 2-methyl-1, 4-naphthoquinone is just the reason why this compound by the efficiency and character of its antihaemorrhagic action is not inferior to the free quinone.

** The urine that was collected during 4—5 days after the injection of the bisulphite derivative of 2-methyl-1, 4-naphthoquinone was evaporated to a volume of 200—250 cm^3 in a current of carbon dioxide at a temperature of 30° and a pressure of 15—20 mm, and repeatedly extracted with ether first from a sulphuric acid medium, and then from an alkaline one. In a separate sample taken from the united ether extracts the absence of 2-methyl-1,4-naphthoquinone and of phthiocol was proved, according to the method of Scudi(5) using cystein. Then the ether was distilled off, a small amount of water was added, the pH of the medium brought to 6—6.5, alcohol added and precipitation was achieved with a lead acetate solution. The precipitated lead salts were filtered off, decomposed with sulphuric acid and extracted with ether. After refluxing the ether solution with animal charcoal and drying it over sodium sulphate, the ether was distilled off. Phthalic acid that separated was sublimed *in vacuo* and identified as phthalic anhydride.

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GEOLOGY

SOME FEATURES OF CHOKRACK BASIN PALAEOGEOGRAPHY IN A NEW ASPECT

By V. P. BATURIN

(Communicated by A. N. Zavaritsky, Member of the Academy, 3.III.1944)

In the volume XII of «The Stratigraphy of the USSR» dealing with the Neogene, B. P. Zhizhchenko, the author of the section of «The Lower and Upper Miocene», has given a number of interesting schemes illustrating the distribution of facies, of thickness of deposits and of the terrigenous-mineralogical provinces in the Chokrack basin (Middle Miocene) of the Caucasus and the adjoining regions. In his conclusions Zhizhchenko has widely used the data of the new mineralogical-petrographic analysis, made by S. A. Blagonravov, and has found out new details in the palaeogeography of the Chokrack basin. At the very first stage of the petrographic study of the Chokrack-Karagan deposits the same problems invited the interest of the author of the present paper, but no palaeogeographic reconstruction was possible because of the scarcity of analytical data then at hand. At present, when studying new data available, we shall make an attempt to retrace the scheme of currents and some other characters of the Chokrack basin palaeogeography, up to now not studied fully enough.

The mineralogical study of Chokrack-Karagan deposits, which has shed some light upon the transportation of terrigenous material, was started by O. M. Ansheless in the Grozny region. O. M. Ansheless determined the quartz composition of sands; as well as the presence of some representatives of metamorphic rocks; namely that of staurolite and kyanite, among other minerals.

Then Z. P. Ivanova, C. N. Pitkovskaya, L. N. Rosanova, V. Fedorov and especially S. A. Blagonravov, found out that the kyanite-staurolite association described by O. M. Ancheless was widely distributed over large areas of the Caucasus in quartz Chokrack-Karagan deposits, being absent only in the Western Transaucasia. In the North Caucasus kyanite and staurolite have been found to occur in Chokrack-Karagan deposits stretching from the Taman peninsula to the northern part of Azerbaidjan and farther on to the central part of Azerbaidjan (Kabristan) within the southern slope of the Main Caucasus ridge. At the Crimea the association has been discovered in the Kerch peninsula. Of similar composition are the sediments correlated with the Chokrack deposits and exposed farther on to the North, in the region of the platform.

A detailed mineralogical study has, moreover, found out some peculiar features characterizing separate territories and permitting to distinguish several terrigenous-mineralogical provinces. The scheme of their distribution may be accepted after Zhizhchenko. Besides the Transcaucasian province greatly differing from all other ones and characterized by the absence of kyanite and staurolite, Zhizhchenko has distinguished the following terrigenous-mineralogical provinces: the Northern province occupying the northern border of the Chokrack basin, as well as the North Caucasian, Grozny, Daghestan and Chale-Dagh provinces.

The data on the Northern province are very poor as yet, but they show, however, that the mineralogical composition of this province differs but little from the provinces of the northern slope of the Main Caucasus ridge, that is from the North Caucasian and Daghestan provinces. The distinguishing feature of the North Caucasian province occupying the western part of the North Caucasus is the presence of andalusite, besides kyanite and staurolite. The mineral composition of the heavy residue of the Grozny province is similar to that of the Daghestan province with the exception of the Lower Chokrack clayey series characterized by a great abundance of rhomboid pyroxenes. According to our analyses and those by S. A. Blagonravov, the heavy residue of the Chale-Dagh province is made up of the same elements as that of the provinces of the northern slope, the decreasing quantity of quartz being characteristic of the light residue.

Fig. 1. Scheme of currents according to Zhizhchenko: *1*, cold currents; *2*, warm currents

Besides the above scheme of the distribution of various mineral association, a lithologic map is also of great importance for establishing the transportation of terrigenous products. Such a map has been also made by Zhizhchenko. In connexion with the analysis of the problems which are of interest to us, the following peculiarities of the distribution of separate facies are to be mentioned: 1)after Zhizhchenko's scheme clayey and carbonaceous sediments were forming along the northern border of the basin, only the character of sediments along the meridian of the lower course of the Volga has not been studied, and Zhizhchenko has not hatched this section due to the lack of data; 2) immediately below this region there is the largest area of sandy deposits; 3) on the periphery of the Caucasian island the deposits are represented by mixed sandy-clayey and carbonaceous sediments.

Taking into consideration the above-said; one may work out a scheme of currents; which is in close agreement with the distribution of separate types of rocks and the boundaries of terrigenous-mineralogical provinces.

To work out such a scheme we have used new current maps of the Caspian and Black Seas; displaying certain similarity to the basin which occupied the southern part of the USSR in the Chokrack time. We have also taken into account the palaeoriver run-off which; though rather neglected formerly, is an important factor for the seas of a semiclosed type. It is quite evident that a considerable volume of water was supplied by the Russian platform, and that some relics of large water arteries are to be looked for somewhere in the North of the Chokrack basin. When investigating the sediments of the littoral zone, rather poorly studied owing to the wide occurrence of Pliocene and Post-Pliocene deposits, we have discovered but a single site where the mouth of an ancient water artery may have existed. This site is represented in the Zhizhchenko map as a white spot and is situated at the meridian in the lower course of the Volga.

Sandy deposits greatly developed immediately southwards speak in favour of delta environments. In basins, like the Chokrack one, the deposits of this kind are usually formed in shallow water, near a mouth of large rivers. Such is, for

instance, the distribution of sediments in the northern part of the recent Caspian Sea. The similarity of the mineralogical composition of the Northern and Grozny-Daghestan provinces also confirms the above suggestion.

The clayey character of littoral sediments found to the West of the discharge of the Palaeovolga (as one may call this artery) permits us to suppose that there were no large arteries there and that even the Don basin might have been involved into the drainage system of the Palaeovolga.

Enormous volumes of river water, on the one hand, and temperature differences in the northern and southern parts of the basin, on the other, created a current directing southwards, bending round the Pjatigorsk projection and going down along the Daghestan part of the Caucasian island. Having rounded the Caucasian island from the East, the current turned to the South, South-East

Fig. 2. Scheme of currents according to the author: *1*, direction of currents; *2*, region of a supposed delta and fore-delta

and, finally, to the North (along the eastern shores of the basin) forming a ring similar to the Caspian one (Fig. 2).

Such a scheme explains the absence of the characteristic element of the North Caucasian province, namely of andalusite, to the East of the Pjatigorsk projection, as well as the presence of northern elements, that is of kyanite and staurolite in Azerbaidjan (the Chale-Dagh province). A small area of more clayey sediments (the stagnant zone) discovered to the NE of the Pjatigorsk projection is well in accordance with such a reconstruction of the dynamics of the basin. The second small area of clayey sediments in the middle course of the Kuban river suggests a second ring-shaped current going counter clockwise.

We have reasons to believe that through the Northern (Crimean) strait and along the southern shores of the Caucasian island the more saline water of the ancient Black Sea poured into the eastern part of the basin. However, these bottom compensation currents could hardly play an important rôle in the transportation of clastic material over considerable distances. The predominance of clayey sediments in the Kuban-Stavropol part of the basin, which seems to have been of a stagnant character, speaks in favour of this suggestion.

Therefore the current scheme proposed by Zhizhchenko is to be fundamentally changed, since it is based only upon the interaction of cold and warm water, lithological and mineralogical data not being taken into consideration.

Further mineralogical analysis will undoubtedly define more accurately the way along which terrigenous products migrated in the Chokrack basin. Of great theoretical and practical interest is the site where the fore-delta and the delta of the Chokrack Palaeovolga are supposed to have existed.

High porosity and permeability of fore-delta sediments (by analogy with the North Caspian sediments) and of some delta deposits enable us to consider this region as an oil prospective area.

Institute of Mineral Fuel,
Academy of Sciences of the USSR.

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MINERALOGY

THE CRYPTOSTRUCTURE OF CLAYS DURING THEIR DEFORMATION

By I. V. POPOV

(Communicated by F. P. Savarensky, Member of the Academy, 29.II.1944)

The features of the structure of rocks; such as their size, shape and relative arrangement of the elementary ultramicroscopic particles, are termed their c r y p t o s t r u c t u r e. The author has studied the cryptostructures spontaneously formed in montmorillonite clays under the participation of adsorbed $Ca^{\cdot\cdot}$ and water, possessing anisotropy of structure and of optical properties. An analogous cryptostructure is produced in the case of $Na^{\cdot}$ participation, not spontaneously, however, but under the influence of the conditions prevailing at the boundary surfaces. The cryptostructural objects built up of the elementary particles with a laminated crystalline lattice, absorbed cations and dipoles of water, have all the features of crystalline bodies, being at the same time capable to change reversibly the translation vector c with a change of the moisture content.

Owing to such differences from the common crystals and a certain resemblance to colloid structures, the author has given to the structures observed by him the name of a n a c h i c r y s t a l l i n e cryptostructures.

In the experiments with a paste of a montmorillonitic Na-clay containing up to 200 per cent water and above, optically anisotropic cryptostructures have also been obtained by applying mechanical force. The observations were made under the polarizing microscope.

When the clay paste is placed upon the object-glass and spread over it, after which it is pressed to the former by the cover-glass, optical anisotropy is already observed in it; being easily detectable between crossed nicols by means of a gypsum plate with a sensitive violet colour of the 1st order. The field of vision is found to be covered with blue and yellow spots, and in some places it remains violet. Passing to a study of the oriented cryptostructure appearing in the clay under the influence of mechanical forces, the author had recourse to the gypsum plate as a method of revealing optical anisotropy.

The same clay paste was placed in a glass pocket between the object-glass and the cover-glass glued along three edges. The deformation of the paste was caused by pressing in and drawing out a mica plate or a thin wire that played the part of dies. As a result, areas of compression and stretching appeared in the clay. The difference in their cryptostructure was disclosed by the gypsum plate which coloured blue over the compressed areas of the paste, and yellow, over the stretched ones, *i. e.* by the appearance of N'_p in the direction of compression, and of N'_g in the direction of stretching.

In the simplest case the appearance of these directions with different refractive indices could be observed upon driving a wire into the paste. At the plane of the cut of the wire entering the paste, where the paste was compressed, a blue

coloration appeared; while along the lateral surface of the wire; where the paste was drawn out; the coloration was yellow. The distribution of the coloration and the optical orientation during the formation of the cryptostructure are shown in Fig. 1.

When pressing the paste which fills the glass-pocket with the edge of the mica plate; the gypsum plate over it was found to assume a blue colour. When

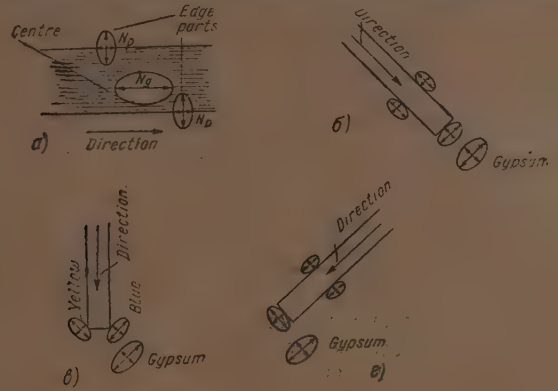

Fig. 1. *a*, optical orientation in a smear of paste of Na-clay; *б*, *в* and *г*, optical orientations in the same paste when driving a wire into it in different directions with respect to the orientation of the gypsum plate shown in the figure

pulling the mica; the paste adhering to its edge was stretched; and on the areas of the paste drawn off a yellow colour appeared. The areas of the paste distant from the edge remained blue; while over the intermediate spots the gypsum plate retained its violet interference colour. The distribution of the coloration and the optical orientation of the compressed; stretched and isotropic areas are shown in Fig. 2.

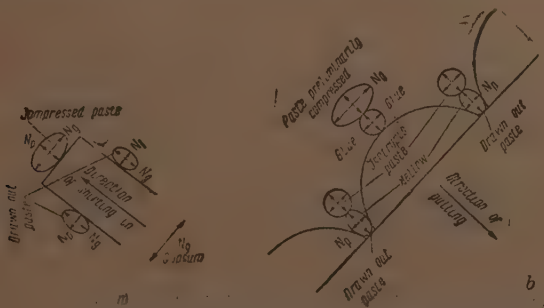

Fig. 2. Optical orientation in the paste of Na-clay, compressed (*a*) and partly stretched (*b*)

Another series of tests with clay paste was run under such conditions where simultaneously with compression the water squeezed-out was removed by means of filter paper; between the little pocket of which the paste was compressed with a press, as it is done when determining the maximum molecular moisture capacity by A. F. Lebedev's method.

The clay thus pressed and dried had a high interference colour. Upon being moistened again with water it was rapidly swelling, showing a banded structure. The optical orientation was the same in all the bands: along the bands; N_g'; and

perpendicular to the plane of pressure (*i. e.* in the direction of pressure); N'_p. It was not possible to determine the optical character.

In order to settle the question as to the orientation of the elementary crystals of clay in the deformed areas of the paste with respect to the direction of the acting strain; reference should be made to E. Schiebold (²); who reports that in crystals with laminar lattices the *c* axis coincides (or nearly so) with the direction of N_p. The author's observations of the optical orientation in the compressed areas of the paste showed that N_p lies in the direction of the acting strain. It may therefore be assumed that it is in the same direction that lies the crystalline *c* axis; and the laminae of the elementary crystals of clay are oriented perpendicular to the direction of pressure. A similar orientation is also found in the alsi-films (alumina-silica films) described by Hauser and le-Beau (³).

Accordingly, in the stretched areas the plates of the crystals lie with their long axis along the direction of the acting strain.

It seems that similar observations and conclusions could be made if the cryptostructure of clay sediments were studied with due consideration of the direction of pressure exerted upon them in the process of diagenesis. A study of the orientation of particles in the cryptostructure of clay rocks which have suffered metagenesis and metamorphism may reveal the rôle and direction of the pressures causing these processes or accompanying them.

Another point is of interest. The pastes; subjected to deformation; contained from 75 to 200 per cent water, which corresponds to a content by volume of 100 to 150 per cent water. Considering that the laminated crystals are in this case parallel to each other; and consequently have no direct contact; the connexion between them and the transmission of stress in the paste should be viewed not as molecular attraction in the case of direct contact; but as effectuated by cations and oriented dipoles of water. Such a necessary assumption is not in agreement with the views advanced of late by some authors on the problem of the mechanism of the connexion between the particles in soils and grounds (¹).

Conclusions. The optical phenomena observed in clay pastes mixed with water in the case of their deformation should be taken to mean that: (a) there exists a relation between the orientation of particles and the direction of the acting strains, and that (b) water dipoles and cations participate in the mechanism of the connexion of mineral particles in aggregates and the transmission through it of stresses from the acting external strain to the mineral particles composing the paste.

V. V. Kuibyshev Engineering Institute.
Moscow.

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PLANT PHYSIOLOGY

ON THE CORRELATION BETWEEN THE ABSORPTION BY PLANTS OF WATER AND MINERAL SUBSTANCES AND ON THE RÔLE OF INTERNAL AGENTS

By E. I. RATNER

(Communicated by A. N. Bach, Member of the Academy, 20.XII. 1943)

The question as to the existence of a correlation between the absorption by plants of water and of mineral substances has not been solved until the present time. The interpretation of the two processes as being independent of each other has recently been the object of revision again [1—4].

Our study of the salt resistance of plants as connected with their water-supply has shown [5] that, the concentration of salts in the soil solution being the same, the supply of the plant (*Hibiscus cannabinus*) with water is largely responsible for its provision with salts.

Later on the existence of a relation between the uptake of salts by the plant and the intensity of respiration has been confirmed by the experiment on varying transpiration intensity in a dry and humid chamber, for the case of absorption by three-week-old barley plants of the chlore ion from equilibrious 20 times diluted Vant Hoff solution.

These experiments are, however, open to objection; for the correlation observed between the absorption of salts and the intensity of transpiration may be referred to the variation in the osmotic properties of the root-cells, due to the increased concentration of salts in the external solution. It is in this way that the question has been treated by Curtis [6]; denying the existence of a correlation between the supply of water and that of mineral salts, this writer believes such a relation to take place in the case of injury caused to the root system by an excessive increase in the concentration of the salts in the external medium.

We do not deny that the rising of the concentration of salts in the external solution beyond a definite limit may be accompanied by a change in the osmotic properties of the root-cells. But in our opinion this interpretation fails to reveal the essence of many a fact which point to the existence of an intimate relation between the absorption of water and that of mineral salts in the case of such concentrations as produce no toxic effect upon the plant. We believe the essence of these phenomena to be closely connected with the mechanism of absorption of mineral substances and their migration along the plant.

The correctness of this point of view has found support in a special experiment by whose means the absorption of potassium and calcium could be studied under conditions of varying transpiration intensity; and moreover, instead of salt solutions it also was studied on suspensions of a permutite containing the cations in an adsorbed state. Under these conditions it was found possible to supply the plant to a sufficient degree with the cations to be tested, entirely eliminating at the same time the possible injurious effect of an increased salt concentration upon the root system of the plant.

In order to obviate the possible objection as to the injurious influence that may be produced upon the root system by an unequilibrious solution or by an alkaline medium, the saturation of the permutite with potassium was not made to exceed 30 per cent to its exchange capacity. The remaining 70 per cent were substituted with calcium. The suspension showed but a slightly alkaline reaction (pH = 7.2—7.3). Lastly, in order to prevent the absorbing effect of transpiration through the ageing parts of the roots (7), we took for our experiment very young plants only, *viz.* 12-day-old plantlets of Indian corn of the variety «Sterling».

The technique of the experiment was the following. The plants were grown in water cultures, on a four time diluted Helriegel nutrient solution. When 12 days old, three sets of them, 38 in each set, were selected; all the plants were identical as to their external appearance. One of these sets served as controls for estimating the content of Ca and K in the plants, previous to the experiment. The two other sets were transferred to a suspension of very fine-ground permutite saturated up to 30 per cent with K and up to 70 per cent, with Ca. The quantity of permutite was so taken as to permit of an addition of 120 mg of K per a vessel with a capacity of about 1.5 l. One of the vessels with the plants was then placed into a spacious glazed chamber with humid air, while another was transferred to a similar chamber whose air was rather dry. The increase of air humidity was attained by placing at the bottom of the chamber broad flat vessels filled with water, as well as of moistened gauze. The walls of the chamber were from time to time sprayed with water. As the weather happened to be extremely dry during the experiment, air was periodically blown through the second chamber by means of a ventilator (the experiment was run in the open). In order to prevent overheating, the chambers were protected from the effect of direct sun-rays. The temperature in the two chambers was kept at about the same level.

By means of a system of rubber-tubes the liquid in the vessels was aerated every 1.5—2 hours during 10—15 minutes with a stop during night, in order to secure aerobic metabolism in the roots and a continuous stirring of the permutite suspension.

The duration of the experiment was 48 hours. The quantity of water in the vessels was kept at a constant level by adding from time to time some known quantities of water.

Table 1

	Dry weight of plants in g	Water evaporated in cm^3	Discovered in plants in mg		Absorbed from permutite	
			K	Ca	K	Ca
Control (prior to exper.)	2.08	—	33,4	12.6	—	—
Plants from dry chamber (intense transpiration)	2.45		72,5	5	1	2.4
Plants from humid chamber (feeble transpiration)	2.37	98	48.2	13.4	14.8	0.8

From Table 1 it may be seen that the relation between the absorption of cations by the plant and its water intake is quite significant. Moreover, a simple calculation is sufficient to demonstrate that this relation cannot possibly consist in a mere carrying away of the cations by the water absorbed by the plant. In order to absorb the amount of K recorded in the table the plants ought to transfuse many a litre of water, since in our case the concentration of soluble K could not exceed a few mg per litre (we mean here the K that might have split off the permutite in the process of hydrolysis). The absorption of cations in our experiment should thus be considered in both runs as an active process; its correlation with water absorption must be underlain by a different mechanism, dependent on some internal factors which are responsible for both the absorption and migration of mineral substances in a vegetable organism.

On account of what has been said here, it seemed us possible to demonstrate that by stimulating those internal agents we might succeed arbitrarily to change the rôle of the transpiration flow in the absorption of mineral substances. On the ground of the considerations further advanced, we chose as the one of such agents the variation in the plant's saturation with mineral substances.

The experiment which had been supposed to clear up this question was carried out under the same conditions as described above. In order to obtain such plants as would differ sharply enough as to their content of mineral substances, the experimental cultures (indian-corn of the Sterling variety again) were grown on Helriegel solution diluted 20 times or on the same nutrient medium diluted twice. The seedlings were taken into experiment when 10 days old. Ana ysis has shown them to contain 0.756 and 1.877 per cent of K, respectively.

Table 2

	Plants poor in K				Plants rich in K			
	Dry weight of plants in g	Water evaporated in cm^3	Total content of K in mg	Absorbed from permutite in mg	Dry weight of plants in g	Water evaporated in cm^3	Total content of K in mg	Absorbed from permutite in mg
Control	1.22	—	9.23	—	1.95	—	36.64	—
Plants from dry chamber (intense transpiration)	1.45	110	18.00	8.77	2.60	180	56.80	20.16
Plants from humid chamber (feeble transpiration)	1.46	55	18.17	8.94	2.78		41.46	4.82

The experiment lasted 48 hours. From Table 2 it may be seen that in the case of plants poor in K the intensity of transpiration failed to affect the absorption of K by the plants from the external medium. Unlike this, in the case of plants rich in K, the intensity of transpiration becomes a decisive factor, determining the plant's ability to a further absorption of this cation from the external medium.

Thus, the question as to the part taken by the transpiration flow in the absorption by the plant of mineral substances cannot be the same in all cases. According to the conditions of the plant (in our case, the saturation with mineral substances), the rôle of transpiration may be either negligible, or rise to the rank of a decisive factor.

These data make us view at a different angle the importance of the concentration of the solution for the evaluation of the part played by the transpiration flow in the absorption of mineral substances. Unlike strongly diluted solutions, those with a high concentration bring about a rapid saturation of the plant with mineral substances; as a result, the part played by the transpiration flow in the subsequent absorption of those substances by the plant becomes more important.

It seems to us that the essence of these phenomena cannot be discussed apart from the question concerning the ways of the migration of mineral substances along the vegetable organism. We have already pointed out (8) that the mineral substances may be assumed to ascend not only along the xylem, but the phloem, as well, by virtue of the surface migration of ions (9).

The principle factor responsible for the direction of the movement of ions (in our case, of cations) from the external cells of the roots towards the internal ones and farther, to the aboveground organs, is the respiration of the cells, more strictly speaking, the hydrogen ion continuously produced in the process of

respiration. At the expense of exchange with this ion the cations migrate; as it were along a conveyer, from such cells as are high in them to less saturated ones. The desorption of the cations into the cellular sap; which is effectuated by means of hydrogen again, keeps the colloids of the cells poor in metal cations. Owing to this, the conveyer continues working in the same direction until the cell, or a whole complex of cells making up a given tissue; remains at a high level of life-activity.

This mode of absorption; however; cannot prevail in a plant until it has attained a certain degree of saturation of the plasm of its cells with metal cations, which is connected with a total increase of the cations' content in the cell. The main fact pointing to the change in the saturation of the cell's colloid elements with cations in the case of an increase of their total content in the plant is the regularity recently set forth by Phillis and Mason [10]; by virtue of this regularity, according as the total content of these cations in the plants increases, a gradually increasing amount of them is found to have passed into absorbed condition in the plant.

According as their total content in the cells also augments, the gradually increasing saturation of the absorbing apparatus of the live cells with cations should more and more impede the further migration of cations along these tissues by virtue of surface migration. Under these conditions the part played by the transpiration flow in the upward migration of cations absorbed by the root becomes more and more important.

The author thus feels inclined to believe that the migration of mineral substances from the roots to the aboveground organs of the plant does not proceed in the same way; either. In plants very poor in these substances and at a high level of their life-activity this migration takes place mostly through their live tissues; through the phloem, so far as we can judge; whereas in plants high in mineral substances; the migration proceeds largely through the xylem, along with the transpiration flow, and is dependent on the latter's intensity.

Under natural conditions the second type of migration must play a particularly important rôle in saline soils; it may be assumed that the transpiration process is the main cause of the accumulation of the large amounts of salts which are frequently found to be contained in plants grown on saline soils. Hence a number of important conclusions is to be drawn for the cultivation of crops on saline soils; especially under conditions of artificial irrigation.

K. A. Timiriazev Institute of Plant Physiology.
Academy of Sciences of the USSR.

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MICROBIOLOGY

ON CERTAIN CONDITIONS OF FORMATION OF INTRACELLULAR VIRUS INCLUSIONS

By K. S. SUKHOV

(Communicated by A. A. Richter, Member of the Academy, 16.III.1944)

Investigations by Sheffield (15), Beal (12), Goldin (2–4) and others have shed sufficient light upon the morphology of the inclusions accompanying the tobacco mosaic, to which we give after Goldin (3) the name of Iwanowsky's crystals or bodies.

Beal has shown that if acted upon with hydrochloric acid, Iwanowsky's bodies are recrystallized into aciculate or filiform elements, similar to the paracrystals of purified Stanley's (16) tobacco virus protein. Sheffield and Goldin (4) have soon after him borne out the morphological distinctions between the inclusions arising in tobacco plants affected by a strain of the common tobacco-mosaic disease, and by a strain of aucuba-mosaic. In the latter case, the affected cells are found to contain, along with Iwanowsky bodies, also annular, loop-like and spindle-like inclusions.

The presence in the same tobacco cell of various forms of inclusions consisting of the same substance points to the heterogeneity peculiar to the plasm; owing to this heterogeneity, the same cell may offer conditions favouring the formation now of one, now of another kind of inclusions. But what is the essence of those conditions, we do not know.

The author (7) observed two forms of virus inclusions accompanying the «zakuklivanie» of oats, the one in the shape of aciculate crystals, the other in the shape of loop-like structures and in *vivo*; the latter were also sometimes found to crystallize into needles. But the cause of these transformations has also remained unknown.

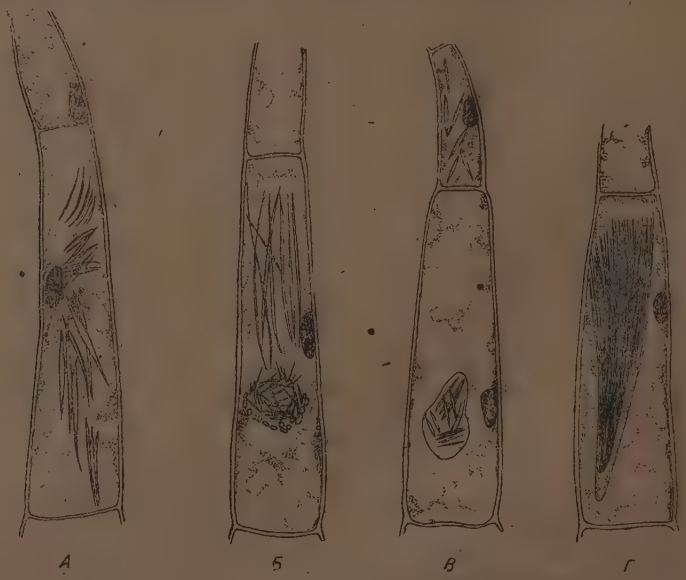
Rischkov and Smirnova (5; 6) have made a large step towards the knowledge of these conditions. They have found that whenever a concentrated solution of tobacco virus is introduced into a colloid liquid, say into a neutral solution of gelatin, egg albumin, starch, sodium salt, thymonucleic acid or into liquid glass; the virus aggregates into large lens-shaped liquid crystalls. This phenomenon approaches in its essence the biological conditions under which proceeds the formation of virus inclusions in cells, the shift of the charge of the virus particles towards the isoelectric point being eliminated here. In all the cases described heretofore the production of virus paracrystals *in vitro* under the action of acids or concentrated salt solution has always been accompanied by such a shift. Besides, the colloid nature of the solutions applied brings the physical conditions of the experiment near to those prevailing in the cytoplasm. Rischkov (6) believes that the artificial production of paracrystals in colloid solutions does well account for the process of their formation in the cell. He refrains, however, from identifying the paracrystals obtained in this way with the inclusions that arise in cells.

Later on Cohen ([13]) has arrived at similar conclusions. Heparin has been found by him to be the colloid which is most efficient in inducing the crystallization of the virus of tobacco mosaic. Up to 75 per cent of the virus albumen used to crystallize from solution in the presence of heparin. Such colloids as agar; gelatin, gum arabic, thymonucleic acid and soluble starch proved also active, however.

If we are to admit that these data shed some light upon the phenomenon of aggregation of the virus substance in live cytoplasm; it certainly fails to do so in the case of the mechanism responsible for the different course of the formation of virus inclusions, as observed, for example, in the case of the tobacco mosaic or the zakuklivanie of oats. Some evidence in this respect is offered by the observations on the changes induced in the virus inclusions by the processes which go on in ageing or dying-off cells.

Observations of this kind have been carried out by the author on Iwanowsky's bodies as material. The cuts prepared from the edge of a mosaic tobacco-leaf were embedded in a drop of vegetable oil and covered with a glass. With the aid of a microscope separate threads could be found to contain in their cells Iwanowsky crystals.

Because of the anaerobic conditions the movement of the flows of cytoplasm ceased soon; giving place to coagulation and disintegration phenomena which led to a desorganization of the structure of the cells.



Virus inclusions in hairs of mosaic tobacco plant subjected to anaerobic conditions

During a certain period of time the Iwanowsky crystals preserved their more or less normal appearance, but by the second or third day they could no more be detected in the cells. Instead of them considerable accumulations of needles, fibrillae and spindles could be seen to arise, or else separate whisk-like structures spreading all over the cell (see figure, *Г*). Some of them took on shapes which were never observed for this virus.

The structures described persisted during a few days and new accumulations of crystals could be observed in individual cells. After some time the picture became stationary and did not change until the 11th day. The observations have not been continued any longer.

Similar alterations took also place in the *X*-bodies which have been described by Sheffield and Goldin as granular accumulations of the virus substance, frequently encountered in the cell along with Iwanowsky's crystals. In this case, however, the formation of needles proceeded within the *X*-body which preserved its shape; as a result, there was formed a round capsule with the needles enclosed in it (see figure, *B*).

This structure of the *X*-bodies makes think of their complex composition; it seems likewise possible that the membrane of the capsula is a product of cytoplasmic reaction.

The variations taking place in the virus inclusions in decayed cells are in rather good agreement with the transformations of Iwanowsky's crystals which have been described to form under the effect of acids. In our case we have to consider as the active principle the organic acids accumulating in the cells according as these die off under anaerobic conditions. Although the changes described proceed in a decaying cell, they permit nevertheless to evaluate the possible influence of the organic acids formed in the process of the metabolism of the living cytoplasm upon the formation of virus inclusions.

And such an influence is the more probable as the reproduction of virus particles proceeds in the depth of the live cytoplasm, in the most intimate organic connexion with the latter.

In addition to this we have some evidence, however, which has been obtained with live material.

When investigating the mosaic of winter wheat we failed nevertheless to detect any specific inclusions in the diseased cells, either in cuts made with live material, or on preparations fixed with neutral solutions. But as soon as acid fixators were applied, composed of such substances as acetic, chromic or hydrochloric acid, or acid salts, virus protein inclusions could be seen to precipitate in the shape of long spindles or bunches of fibrillae ([8],[9]). It is obvious that the effect of the fixator should be divided in this case into two phases. At the first instant after the penetration of the acid into the cell it is the change in the pH which is operative, bringing about the precipitation of the virus protein. At the next moment, along with an increase in the concentration of the acid, there takes place the fixation of the cell itself and of the inclusions formed.

If a portion of a mosaic wheat-leaf is macerated with the aid of a needle in a drop of a 0.1 *N* solution of hydrochloric acid, a considerable amount of proteinic fibrillae or of crystalloid needles is found to form in it. If a diseased leaf is macerated in a drop of water, there never takes place formation of these structures.

A different kind of behaviour is shown by old, yellowed, but still turgorescent and not decayed leaves of plants affected with mosaic. When macerating such leaves in water we were more than once able in obtaining the suspension of numerous protein needles ([10]).

In this case the effect was obviously due to the acids which accumulated in old, degenerating but still living cells.

Vovk ([1]) who studied later on the mosaic disease in cucumber (*Cucumis virus* 2 Bewley) has also revealed similar relations. In young and mature leaves virus inclusions were absent, and they did not appear until acid solutions were applied; in very old mosaic leaves, however, they arose spontaneously, without any artificial intervention.

The data referred to above enable us to conclude that the formation of the virus inclusions in the cell is a complicated process; it is controlled, on the one hand, by the colloid properties of the cytoplasm, on the other, by the peculiarities and state of the metabolism of the cytoplasm.

Bawden and Pirie ([11]) have shown that the purified virus of the tomato bushy stunt crystallizes in the shape of rhomboic dodecahedra. The same virus has recently been reported by Cohen ([14]) to crystallize in the presence of heparin quite in a different shape, *viz.* in the form of octahedral prisms; and when the mother liquor of the virus is added anetol, a third, rhombohedral variety of the crystals is obtained.

A vegetable cell which is a highly diversified biochemical medium can also be supposed to contain some substances which may affect the formation of virus inclusions.

Lastly a decisive rôle in the shaping of the structure of virus inclusions belongs to the physical-chemical composition of the virus. And it is this factor which accounts for the specific differences between the shapes assumed by the inclusions in the case of different virus diseases affecting the same plant species.

Laboratory for Plant Virus Diseases.
Institute of Microbiology.
Academy of Sciences of the USSR.

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PARASITOLOGY

A COMPARATIVE STUDY OF THE DEFENSIVE REACTION OF THE ORGANISM OF VARIOUS ANIMAL SPECIES TO PARENTERALLY INTRODUCED LIVING NEMATODES

By I. M. VINNITZKY

(Communicated by I. I. Schmalhausen, Member of the Academy, 22.IV.1944)

Up to the present the manifold problem of the mutual ecologic relations of the two components of the «parasite—host» system has mainly been studied in the light of the influence of the parasite on the host; and only of late some interest is being paid to the natural influence of the host upon the parasite.

It seems, however, desirable to trace new experimental ways for the investigation of this problem. Particular interest belongs to the experimental introduction of living parasites into the organism of animals. With this purpose in view we arranged for the first time in 1936 experiments with the surgical introduction of living and in later experiments also of dissected and dead ascarides into the peritoneal cavity of various animal species.

Methods and Experimental Basis. Our experiments were made on 30 guinea-pigs, 10 rabbits, 24 cats, 32 puppies and adult dogs and 5 hens. We used, besides these, 68 guinea-pigs, 61 puppies and 15 cats for a study on ascaride intoxication and the specific ascaridocidal and antitoxic immunity.

The animals (guinea-pigs, cats, dogs) bear well the operation (under aseptic conditions) and the live ascarides introduced even in great numbers do not provoke any important clinical symptoms. This curious phenomenon of resistance finds its explanation in the fact that the ascarides continue living for some time in the peritoneal cavity, secreting but little toxin at this early stage, so that the organism is able to mobilise its forces to resist and to elaborate antitoxin.

The introduction of dissected or killed ascarides into the peritoneal cavity leads to the death of the experimental animals: a very quick one in the former case, due to the action of the capillary toxin (the cavity liquor of the ascarides), and a slower one in the latter case, as an effect of protracted intoxication ending in complete exhaustion of the organism. The animals which had been immunised by a previous introduction of living ascarides, resist repeated introductions of dissected and killed ascarides.

Ecologic Observations. The length of life of the ascarides (*Ascaris suum*, *Toxocara canis*) in the peritoneal cavity varies with the animal species used and also with the age of the animal and the number of ascarides introduced. The maximum length observed was 10—12 days.

In a number of cases we were able to observe a fact most interesting both from the biological and medical point of view: the ascarides show a tendency to leave the unusual medium (the peritoneal cavity) and are able to bore themselves into the wall of the intestinal tract, to penetrate into its lumen and to

pass through the entire digestive tube. One case of gastric perforation has also been observed.

During their life in the peritoneal cavity the ascarides are able to feed; in particular, on blood, the presence of which in the intestinal lumen of the parasites has been established under the microscope.

Comparative Study of the Response of Animals Belonging to Different Species. The animal organism responds to the presence of ascarides in the peritoneal cavity by defensive reactions varying as to the species.

On the ground of literary data it may be presumed that granulation growth (capsules) is formed around the ascarides which have in some way or other penetrated into the peritoneal cavity, as well as around their eggs. Enzymes seem to play a part in the resolution of the ascarides and their eggs. These ferments are secreted by various cells, by the giant cells among others. Direct phagocytosis also takes place. At the same time calcification of the parasite's composing parts and of its eggs; in particular, also occurs.

In our experiments on guinea-pigs the ascarides have been found to incapsulate in connective tissue elements. In most cases more or less extensive coalescence of the abdominal organs could be stated at the climax of the process. The complete resolution of the incapsulated parasites is achieved mainly by means of phagocytosis under participation of polynuclear cells (microphages) in the first stage and later of mononuclear ones (macrophages). Both show a high activity penetrating through the cuticle and through the membrane of the eggs of ascarides. A definite part in the resorption of the ascarides belongs probably to enzymes secreted by cellular elements.

The resorption of ascarides in guinea-pigs proceeds at a rather low rate. The process of phagocytosis was at its highest by the 33—35th day after the operation. In guinea-pigs sacrificed on the 57th and the 62nd day after the introduction of ascarides; there remained no trace of them.

The process takes a somewhat different course in rabbits. As our experiments demonstrate, the most impetuous leucocyte exudation and granulation typical of the rabbit leads to a speedy death of the ascarides and their early incapsulation within the peritoneal cavity, as well as to multiple coalescences between the abdominal organs. However, the over-abundance of leucocytes retards or even completely stops phagocytosis. In spite of the formation of a powerful rampart of polynuclear cells around the parasite, in no case did we observe a penetration of leucocytes into the cuticle, eggs or any organ of the ascarides, which is so characteristic of the phagocytosis in guinea-pigs. The nuclei of the polynuclear cells suffer a speedy caryorhexis and caryolysis. The leucocytes surrounding a necrotized ascaride are transformed into a structureless necrotic mass in which even by the 47th day after the operation eggs may be found lying which have kept intact their typical structure, as well as separate organs or entire ascarides.

An entirely different picture of the necrobiosis of ascarides has been observed by us in the peritoneal cavity of *Carnivora*. The necrobiosis of ascarides in dogs and cats proceeds without any incapsulation and takes the form of a very speedy lysis directly in the peritoneal cavity itself. The rate of this lysis depends on the number of ascarides introduced and on the individuality of the responding organism.

Complete lysis of 2—3 live ascarides introduced into the peritoneal cavity of *Carnivora* is, as a rule, achieved within 9—12 days. We must note the extraordinary lytic power of the organism of dogs and cats. Thus; 31 *Ascaris suum* varying in length between 20 and 30 cm, introduced into a cat (weighing 2800 g) were found to be completely lysed at the autopsy on the 42nd day after the operation. In the course of a microscopic study of films prepared from the cavity liquor of cats obtained in the course of the lysis of ascarides and soon after its completion, our attention was attracted by the great numbers of neutrophile polynuclear cells observed in them and by the presence of monocytoid cells;

showing; according to their size, a number of forms transitory towards very large and active polynuclear macrophages.

A macro- and microscopic study of the ascarides at the different stages of their lysis revealed the following picture: the ascarides which lose their elasticity are surrounded by polynuclear cells immigrating freely into the peritoneal cavity. Later on they penetrate into the parasite through its cuticle, and this results finally in its infiltration by the cellular elements of the exudate. By the end of the process only remnants of the cuticle and the eggs, surrounded and permeated by cells phagocyting them, is all that remains of the ascaride. Besides active phagocytosis, the action of enzymes seems to play a significant part in the resolution of the ascarides.

The essential circumstance of which we thus become convinced is that the process of necrobiosis of ascarides in cats and dogs shows a great similarity with the analogous phenomena in guinea-pigs, the only significant difference is that granulation growth never occurs in the *Carnivora* and there is no tendency whatever of capsule formation around the parasite. We must emphasize that on no occasion did we observe coalescent loops of the intestine or any concrescence of other organs of the peritoneal cavity.

Live ascarides introduced into the peritoneal cavity of hens were subjected neither to phagocytosis nor to lysis, they were simply mummified.

Comparing the experimental results reported above with the data concerning the incapsulation of parenterally living mature nematodes and their larvae, one must conclude that, in spite of many characteristic histological distinctions, the picture is essentially coincident in all cases, namely:

a) in that of nematodes which have in some way spontaneously left the intestinal cavity or have been artificially introduced into the peritoneal cavity (incapsulation of ascarides in human beings; in guinea-pigs and in rabbits);

b) in that of migrating larvae, the further development of which is stopped by incapsulation (larvae of *Ascaris lumbricoides*, *Toxocara canis*, *Parascaris equorum*, *Nippo strongylus muris*, *Ankylostoma duodenale*, *etc.)*,

c) in that of larvae for which incapsulation forms a necessary stage of their life cycle (incapsulation in the absence of an intermediate host—*Oesophagostomum dentatum*, *Oes. brumpti*; incapsulation in the intermediate host—*Aelurostrongylus abstrusus*; incapsulation in the course of a development cycle involving a change of host, each of them acting both as chief and intermediate host—*Trichinella spiralis*);

d) in that of mature nematodes with a parenteral habitat, which are incapsulated only in their dying stage or after death (*Setaria labriato-papillosa*, *Hepaticola hepatica*);

e) in that of mature nematodes which under natural conditions inhabit the granulation growths induced by them and multiply within these growths (*Onchocerca volvulus*, *Onchocerca flexuosa*);

f) in that of nematodes which are incapsulated both in their stage of maturity and in their larval stage (*Spirocerca sanguinolenta*).

Significance of the Histogenic Defensive Reactions of the Host Organism. In all the cases enumerated above the organism essentially responds to the parasite which has penetrated into it, in the same way as it does to foreign bodies and to pathogenic agents in general: by exudative processes, immigration of phagocyting cells and, finally, by proliferation of connective tissue elements which achieve complete incapsulation of the parasite. It is clear that what we observe is a characteristic defensive reaction, elaborated in the course of evolution, the significance of which consists, on the one hand, in the isolation of the parasite, in immuring it within a solid connective tissue wall, and on the other hand, in its destruction with the help of phagocytosis. If this reaction is considered at this angle of view, we are obliged to acknowledge that the organism is far from being able to destroy the capsulated helminth in every case. Incapsulation may, moreover, become fatal to the host and most expedient or even necessary to the parasite.

This is explained, on the one hand, by the imperfection of the reaction as such, but mainly by the circumstance that the struggle between the components of the «host — parasite» system, going on for an indefinite lapse of time, leads to the development of an ability to neutralize the fatal effect of the incapsulation reaction by the parasite and to the adaptation of the latter's life cycle to it.

In this light special importance belongs to the more perfect phagocytic and fermentative defensive response, developed in the course of evolution, which we have reproduced in our experiments on dogs and cats. This reaction does not result in the incapsulation of the parasites and is absolutely fatal to the parasite subjected to lysis.

The idea suggests itself that the specific character of the mesenchyme response of *Carnivora* is due to a shift in the time of occurrence of the two components of the defensive reaction of the organism to the presence of the parasite; *viz.* the process of its incapsulation and that of phagocytosis.

The prevalent and, doubtless, the most common form of defense is such a reaction of the organism in which the granulation process, *i. e.* the incapsulation (isolation) of the parasite, precedes the immigration of the phagocyting cells, or both proceed simultaneously. In this case the time taken by the phagocytosis of the incapsulated parasite may be greatly protracted or sometimes the phagocytosis may be entirely lacking.

In the *Carnivora* the evolution of the defensive reaction of the organism has led to the following results. On the one hand, the phagocyting cellular elements of the mesenchyme have acquired in these animals a maximum mobility and activity. In our experiment they migrate freely into the peritoneal cavity and show the highest phagocyting and primarily fermentative abilities, resulting in a most speedy lysis of the parasite. On the other hand, the proliferation of the connective tissue, which leads to the incapsulation of the parasite and at the same time to possible organ concrescences in the abdomen; is retarded, and in this case, as an unnecessary process, it is entirely eliminated*.

It does, not, however, seem correct to presume that the particular characteristics shown by the lysis of nematodes in the peritoneal cavity of *Carnivora* have been worked out as a special defensive measure against the parasites inhabiting the cavity, such a case being relatively infrequent and exceptional in the life of the organism. The contrary seems more probable: the peculiar character of the lysis of ascarides in the peritoneal cavity of predatory animals depends on the constitutional characteristics of their mesenchyme, developed in the course of the general evolution of their phagocytary system which has reached in the *Carnivora* at the actual stage of their development a higher perfection as compared to other animals.

General Biology Department.
V. M. Molotov Medical Institute in Tomsk.

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* It is obvious that if one introduces into the organism of *Carnivora* some foreign body which may be resorbed but with difficulty, or cannot be resorbed at all, it is incapsulated by the connective tissue in the usual way. This is proved by numerous experiments involving the introduction of foreign bodies into the peritoneal cavity of *Carnivora*, *e. g.* by these of Albitzky (thesis, 1917), who introduced into the peritoneal cavity of dogs rubber tubes, pincers, catheters *etc.* and found them there incapsulated after a long interval.

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